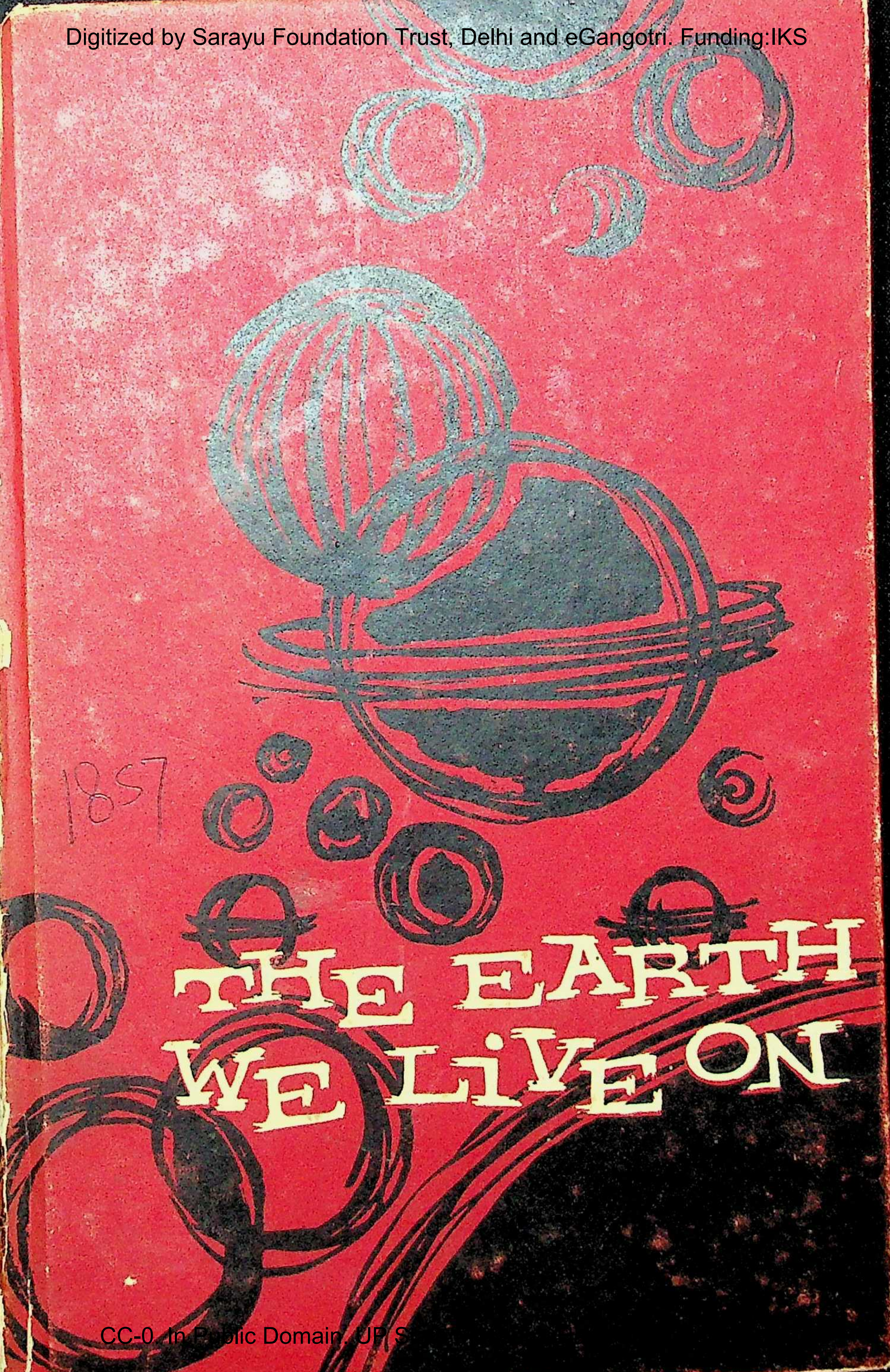
1857
THE EARTH
WE LIVE ON

General Education Reading Material Series
No. 9

THE EARTH WE LIVE ON

ALIGARH MUSLIM UNIVERSITY
GENERAL EDUCATION READING MATERIAL SERIES

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DIRECTORATE OF

GENERAL EDUCATION READING MATERIAL PROJECT

ALIGARH MUSLIM UNIVERSITY

THE EARTH WE LIVE ON

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FOREWORD

The vital role that general education can play in our universities is now being gradually recognized in academic circles. The Radhakrishnan Commission Report published in 1950, first emphasized the need for general education and made certain recommendations for its provision. The Ministry of Education organized conferences and seminars and drew the attention of universities towards its significance. A number of teachers and scholars drawn from various universities visited the United States and the United Kingdom to study the working of general education at various centres and to get first hand knowledge about the progress of various programmes of study. The University Grants Commission has now engaged the services of an expert to advise Indian Universities on the implementation of general education programmes and fifteen universities have already made these programmes a part and parcel of their regular course of studies.

Aligarh Muslim University was among the first to adopt a full and integrated programme of general education courses. Experience showed clearly the need for reading material to be especially prepared for the purpose of this new type of teaching which differs from the traditional one in method as well as in content. When approached, the University Grants Commission entrusted Aligarh Muslim University with the task of preparing reading material suitable for general education courses at Indian universities.

The series here presented, like general education itself, may not find agreement among all concerned. It is not meant to serve as a text which would be completely digested, let alone memorized or crammed. On the contrary it is intended to arouse curiosity, stimulate thinking and broaden the outlook of our students. The selections and samples are expected to enable students to use their intelligence and widen their understanding and appreciation. They may lead to a sense of values urgently needed today.

Another important and accepted aspect of general education is its complementary character. In our country, there is a great and urgent need for more people who are properly trained and educated to earn a living through performing competently the many func-

tions on which our society depends. It is equally important, however, that colleges and universities also impart an education which enables students to live a fuller and more rewarding life. To quote the Report of the University Education Commission (pages 118-119): "The interests and opportunities and demands of life are not limited to any few subjects one may select to study. They cover the entire range of nature and of society. That is the liberal education which best enables one to live a full life, usually including an experience of mastery in some specialized field. . . ." To a student "a general education course should open windows in many directions, so that most of the varied experiences of his life and most elements of his environment, shall have meaning and interest to him."

The task, then, in preparing reading material for general education purposes was clear as well as complex. On the one hand, the mounting walls between the ever-increasing number of compartments of specialized knowledge had to be disregarded so that fragments could be re-assembled into that unity of knowledge which exists in human experience. On the other hand, it was necessary to present only so much of content as students in all traditional branches of knowledge could be expected to manage and to understand as an integrated whole. For, as Whitehead rightly remarked, "a student should not be taught more than he can think about."

Furthermore there is agreement that integration cannot be achieved by providing students with readymade opinions concerning questions that arise in the course of general education. On the contrary, if they are to be encouraged to think for themselves and to seek their own answers, they have to be confronted with errors of the past or doubts of the present, with divergent judgements or open alternatives, as well as with the beauty of scientific proof or the force of moral conviction.

The complete scheme of this series will be found on page ii where a systematic list of the publications is shown. While it adheres to the traditional division into Natural Sciences, Social Sciences and Humanities, many of the expository volumes straddle more than one field, and most of the source material touches upon problems not easily assigned to any one area only.

No student is likely to read and absorb all volumes; but every

student will find instruction and inspiration in several of the volumes if he uses them properly under the guidance of his teachers. Large though the collection is, it cannot possibly aspire at complete comprehensiveness. Since "selection is the essence of teaching" (Whitehead) it had equally to be the principle of planning of this series. And since choice implies omission, many important disciplines had to be somewhat neglected, and others to be left out entirely. Unavoidably, what is here regarded as the result of careful consideration, may elsewhere appear as arbitrary.

The readers of these volumes, teachers and students alike, are the ones whom this publication wants to serve. From them, too, the authors, compilers, editors and advisers of this project hope to hear. It represents a co-operative effort in preparation and publication. Its success depends on further co-operation between "producers and consumers." Comments and criticisms are invited, to be addressed to: The Director, General Education Reading Material Project, Azad Library, Aligarh Muslim University, Aligarh. Since it is planned to translate the series into Hindi and Urdu, changes which may seem desirable, can easily be introduced when this is done.

In the end, the University acknowledges with gratitude the services rendered by the various contributors, reviewers, and the members of the Advisory Committee and all those due to whose keen interest and ready co-operation, the Directorate has been able to complete the Project. We are particularly grateful to the University Grants Commission who entrusted us with the task and assisted us liberally in this venture.

B. H. ZAIDI
Vice-Chancellor

Aligarh Muslim University, 1962

PREFACE

"A man needs to rub up his geography these days." This statement, which appeared in the *London Times* in 1848, is more true today than it ever was. Anyone teaching Geography at the University level is aware that even those students who offer Geography as a subject generally lack a proper understanding of the fundamentals of the science. It was this realization, along with the feeling that all intelligent people should have some knowledge of the earth on which they live, its nature and place in the universe, its physical laws and phenomena, and its resources and people, that prompted the General Education Reading Material Project, Aligarh Muslim University, to include Geography in the list of requirements for students preparing for a University degree.

Students who do not present Geography as an optional subject in their degree course frequently express a great dislike for it. Probably this is due to the fact that most people think of Geography as being a mere catalogue of names of rivers, mountains, towns and so on. However the subject is much more than this; while there may be no general agreement on its precise definition, Geography today is accepted as the study of the relationship between man and his environment.

In this book I have aimed at covering the fundamentals of physical geography which may be regarded as a body of basic principles of earth science. Much of the material in this book is neither new nor original, but I have attempted to present it in such a way as to stimulate the interest of the reader and to provide him with a usable, simplified body of knowledge which is an important part of the foundation for studies of human geography. A list of books for further reading has been included towards the end.

To the Directorate of this Project, I owe a debt of gratitude for the invitation to write this book. I should also acknowledge my debt to all those standard text-books, far too numerous to mention individually, from which I have consciously or unconsciously drawn my material.

AUTHOR

ACKNOWLEDGEMENTS

The Directorate acknowledges with gratitude the services of Dr. M. Anas and Mr. Moonis Raza in the writing of this volume, and of Prof. H. Rahman who revised it and Prof. S. Sethna who reviewed the MS. for us and gave valuable suggestions.

Editors

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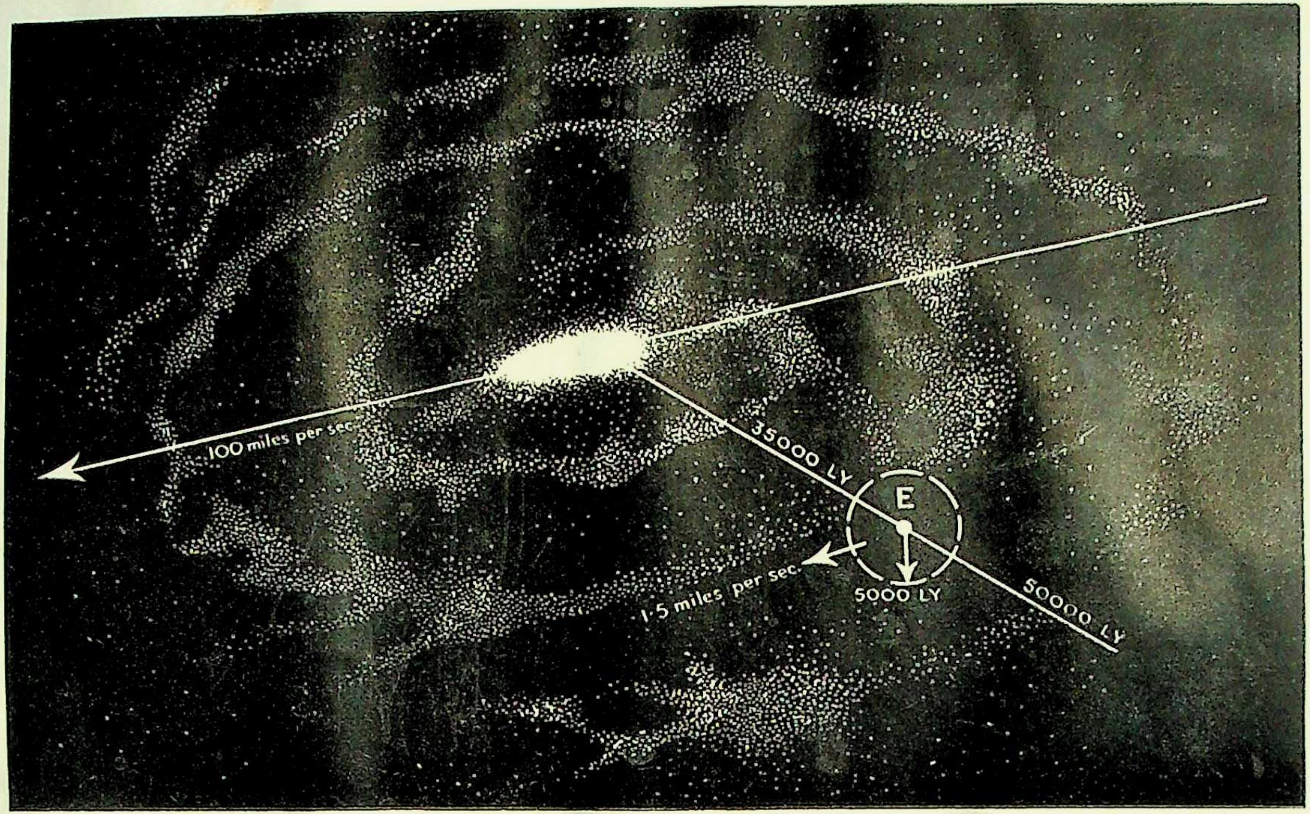

Fig. 1.—EARTH'S POSITION IN THE MILKY WAY.—The earth (shown as E) is supposed to be 35,000 light years (L.Y.) from the centre of the Milky Way, which is a galaxy of 200,000,000 stars. The circle around E with a radius of 5,000 L.Y. represents the area which can be explored by our telescopes.

CHAPTER ONE

THE EARTH AND ITS NEIGHBOURS

The Universe and the Solar System

THE Earth is our home and it is a wonderfully sweet home. It is impossible to describe all the useful, attractive and mysterious things which are found on the Earth. Some of these things are given by Nature, while others are made by Man. There are mountains and plains, forests and deserts, rivers and oceans, towns and villages, houses and streets, mines and farms, factories and markets —all of which make life worth living. We human beings, proud of our possessions, consider ourselves superior to all other creatures. We are apt to think that our Earth is the most marvellous place in the entire universe. In fact, throughout the ages and until as recently as four hundred years ago men were so much impressed by the vastness of the Earth, by the variety of landforms and life on its surface, that they regarded their planet, the Earth, as not only "marvellous" but as actually the "centre" of the universe. Strictly confined as they were to their planetary prison—to the thin crust of the Earth—it was quite natural for them to regard their planet as the most important of all heavenly bodies.

Today, however, we know it for certain that actually the Earth is not the most important planetary body, and that its place in the entire scheme of the universe is quite insignificant. It is merely a small globe, not more than about 8,000 miles in diameter, and a dwarf in the Sun's family. In other words, it is only one of the nine planets which are circling round a central star that is our Sun. Let us understand that the Sun's Family, or the Solar System (i.e., the Sun together with all the great and small planets which circle it), occupies only a very small part of our Galaxy, which we call the Milky Way and which consists of billions of stars. Let us recall that the Milky Way is by no means the only galaxy in the vastness of Space, that the Sun is by no means the only star in this Galaxy, and that the Earth is by no means the only planet circling round the Sun. Does it hurt your vanity to learn that the Earth is no more important than a single particle of sand in the

vastness of a desert? And yet the Earth is a truly wonderful home for us. It gives us sustenance and has made us what we are. Its story, which is only a part of the story of the Solar System, is indeed very strange and fascinating.

The Sun's Family

We may begin this story with the Sun itself, which is the head of its family. Being a relatively large body, it exercises an enormous gravitational pull by which it keeps our Earth and all the other planets in their respective courses—and thus holds the entire Solar System together. "Sol" is the Latin word for "sun" and the term "Solar System" means the group of heavenly bodies which are held in captivity by the Sun. These heavenly bodies include nine large planets (the Earth being one of them), a large number of asteroids (which are very small planets), and numerous very small bodies which we often see in the night as meteors or "shooting stars". All these bodies move in almost circular paths round the Sun, from whose gravitational pull they just cannot escape.

As can be readily seen, the "stars" are bodies in Space outside our Solar System. The distances which separate them from one another as well as from the Solar System are so enormous that they cannot be easily comprehended by the human mind which is accustomed to reckoning distances in units of miles or kilometres. We often forget this fact when we talk these days about the prospects of space-travel. It is true that scientists have been able to launch space-ships and the day has come when space-travel has become a reality. But let us remember that even the fastest ship cannot carry us very far out in Space, and that when we say "space-travel" we are really speaking of journeying to only the nearest planets within our own Solar System.

Let us examine Table I to get an idea of what we are talking about.

While writing these figures is easy, it is rather difficult to imagine the distances which they represent. Have you ever tried to imagine how much distance one million miles cover? Well, for travelling one million miles you will have to go round the world at the Equator no less than forty times! Now, imagine what a distance

TABLE I

Planet	*Average Diameter (miles)*	*Average Distance from the Sun (miles)*
Mercury	5,500	36,000,000
Venus	7,600	67,000,000
Earth	7,967	93,000,000
Mars	4,200	1,42,000,000
Jupiter	85,000	4,83,000,000
Saturn	72,000	8,86,000,000
Uranus	30,900	17,83,000,000
Neptune	33,000	27,93,000,000
Pluto	not known	36,66,000,000

of 3,666 million miles means. This is the distance between the Sun and the outermost planet, Pluto. Isn't it enormous?

Let us try to represent the Solar System upon a scale which may be more within the range of our ordinary experience. Make the Sun a globe 600 feet in diameter. If this globe is placed in Delhi, another globe with a diameter of only 2.5 feet placed at a distance of 485 miles (say near Banaras) will represent the outermost planet, Pluto. Other planets can now be filled in. Neptune with a diameter of 19.5 feet will be at a distance of 370 miles (somewhere near Allahabad); Uranus with diameter of 22 feet will be at a distance of 236 miles (near Kanpur), Saturn with a diameter of 51 feet will be at a distance of 117 miles (near Firozabad); Jupiter with a diameter of 64 feet will be 64 miles (near Khurja). The asteroids ranging from 1/10th of an inch to 3 inches will be at a distance of about 30 miles from Delhi. The remaining planets, Mars, Earth, Venus and Mercury (with diameters of 3 ft., 5½ ft., 5¼ ft. and 2 ft. respectively), will be at distances of 18½ miles, 12½ miles, 9 miles and 4¾ miles from the Sun.

From this model you can see that the Solar System may be divided into two groups. The first consists of the four planets which are close to the Sun, while the second consists of the four outer planets which are gigantic in size and separated by vast distances. Between the two groups there is a broad belt in which are found several thousand small bodies (or asteroids).

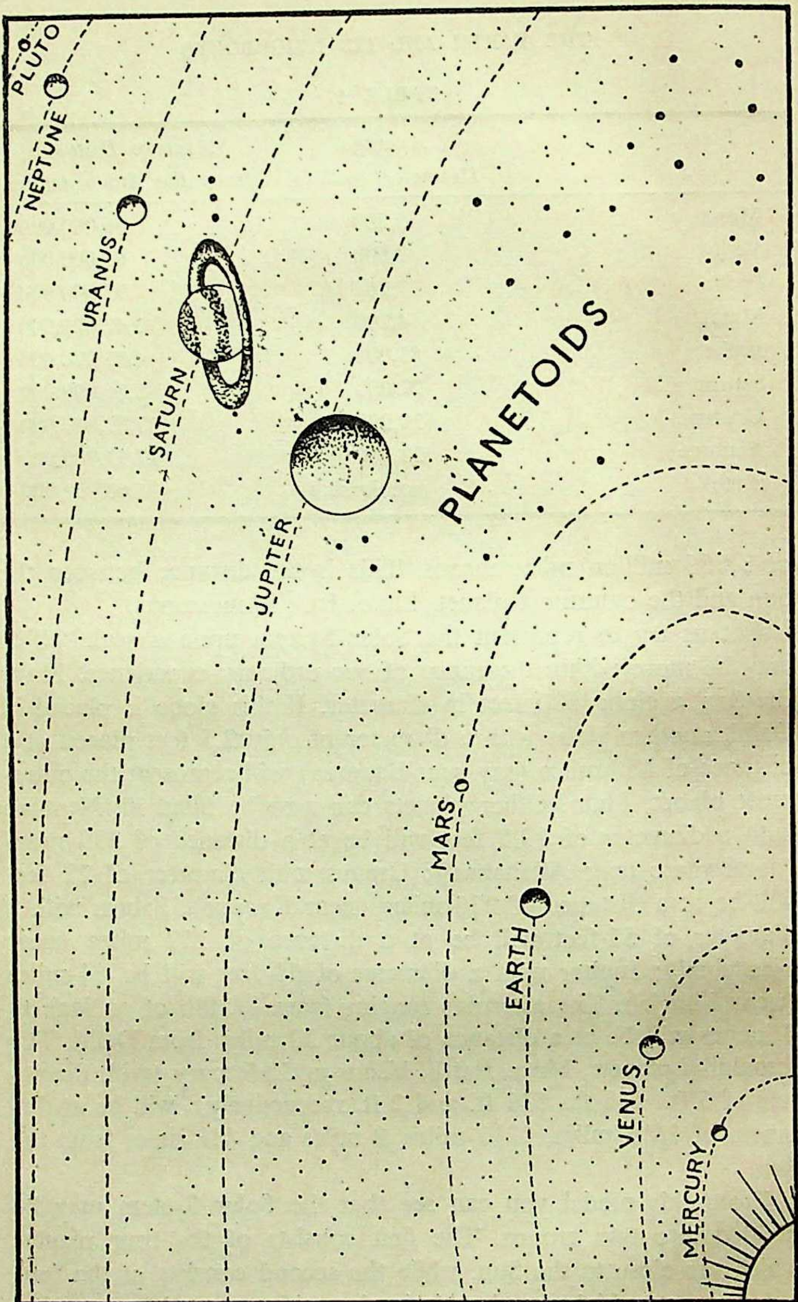

Fig. 2—THE SUN'S FAMILY—The inner half of the solar system has four small planets. The "giant planets" in the outer half are very widely dispersed.

It seems that the position of the planets in the Solar System is governed by a certain law. This law was first discovered by Titius in 1766, and six years later was published by Bode, so that it is known as Bode's Law. This law can be worked out by three progressive steps as follows:

Write down a series of numbers beginning with zero and followed by 1, and then double each successive number—thus:

0 1 2 4 8 16 32 64 128

Multiply each number by 3, so that you have:

0 3 6 12 24 48 96 192 384

Add 4 to each number, so that the result is:

4 7 10 16 28 52 100 196 388

These figures roughly indicate the spacing of the planets, for if you suppose the distance between the Earth and the Sun as 10, then the relative distances of the planets from the Sun work out as:

3.9 7.2 10.0 15.2 26.5 52.0 95.4 192.0 307.0

Science has yet to explain the cause of this systematic arrangement of planets in the Solar System. But isn't this arrangement queer?

The Sun—The Basis of all Life

For us the Sun is the source of warmth and light. It is the very basis of all life on our planet. Without the light and heat which the Sun gives out so generously, we should perish from cold and hunger. In fact, if the heat of the Sun were cut down by as much as only 10 per cent, a large part of the Earth would turn into an ice-bound desert.

Most of the mechanical power which we use today is derived from coal. And what is coal? It is really the sunshine of the past which was stored in giant ferns and primitive trees some 400 million years ago. What marvellous tasks the Sun does for us every day! It causes the winds to blow by warming the surface of the Earth; it lifts millions of tons of water from the sea high into the clouds which give us rainfall. The winds, the rivers and the waterfalls—all owing their existence to the Sun—give us mechanical power. The green leaves of plants absorb the radiant energy of

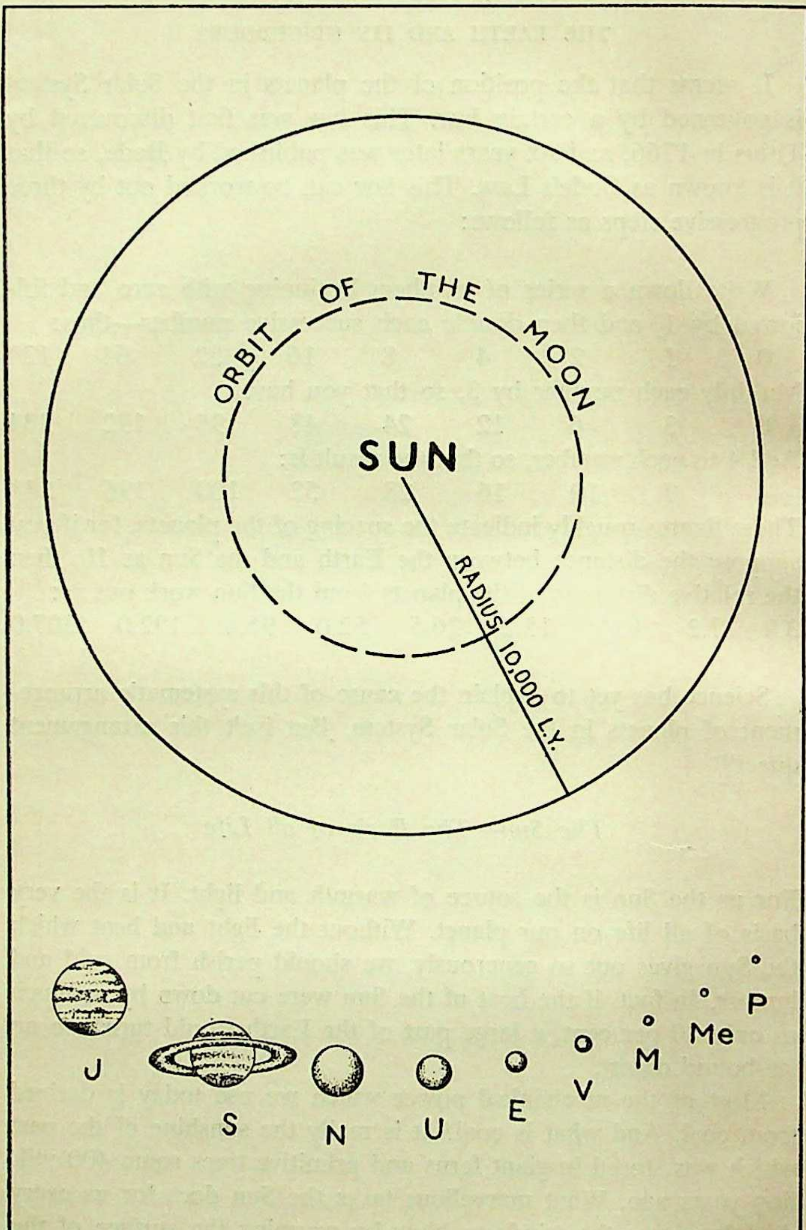

Fig. 3—RELATIVE SIZE OF THE SUN AND THE PLANETS—The circle inside the sun represents the orbit of the moon.

the Sun and grow, so that we have food and fodder. The Sun is our life-giver and in a sense we are all children of the Sun.

Men have always regarded the Sun as their great benefactor. Many centuries ago the Inca people of Peru called themselves "children of the Sun" and even today a number of tribes in the Pacific Islands regard themselves as descendants of the Sun. The Japanese and the Suryavanshi Rajputs of India also consider the Sun as their ancestor. The ancient Greeks and Egyptians worshipped the Sun, and even at present several communities regard the Sun as a god. Whether the Sun is a god or not it is the bestower of all life on the Earth and a great dictator governing the motion of all the planets.

With the aid of special instruments scientists have discovered that the Sun is a great ball of fire measuring about 865,400 miles in diameter. It is about a million times larger than our Earth and nearly 333,000 times as heavy. Its surface temperature (10,000°F.) is enough to turn all solid substances into gas, while its central parts must be as hot as 20,000,000°F.—an indescribable inferno, a veritable hell.

What is the source of this intense heat? It cannot be accounted for by the simple process of burning like the burning of a piece of charcoal, because if the Sun had been burning in that way, it would have been reduced to ashes long ago. It has, therefore, been suggested that the immense amount of heat and light given out by the Sun may be due to its slow contraction. If we accept this view, we can expect that the process of contraction will keep the Sun alive for at least another 10 million years. The most plausible theory, however, is that the intense heat of the Sun is caused by radio-activity or the release of energy by the "destruction" of matter.

Through a telescope the Sun does not look like a ball of fire, but appears as a broad, round, white or golden disc, marked here and there with black patches that look like big holes or caves. These patches are sun-spots which are caused by great magnetic storms. They can be observed any time but for some reason they become more prominent at regular intervals of eleven years.

The surface of the golden disc of the Sun is called "photosphere" (light sphere). The photosphere is surrounded by a reddish layer of incandescent gases which is known as chromosphere (colour

sphere). From the chromosphere jets of fire shoot up to millions of miles into Space. Beyond the zone of leaping flames, there is a halo, the "corona", whose pearly glow becomes visible to us during the eclipse of the Sun.

The Planets

Although our present telescopes and cameras penetrate far into the sky to probe its secrets, it must be admitted that our knowledge of the planets remains rather meagre and sketchy. There is no doubt, however, that we have now definitely entered the era of planetary research. Various kinds of rockets, missles and spaceships equipped with very efficient recording instruments are being used to explore the planetary world and increase our knowledge of the neighbouring heavenly bodies.

What are the various planets like? Let us look at them one by one.

Mercury. The diameter of Mercury is about 3,000 miles, which means that it is only 1/20th of the size of the Earth. Its density is 4.1—that is, it is just about 2/3rds as heavy as the same volume on the Earth. The surface gravity of Mercury is much less than that of the Earth—so that while you may weigh 120 lb. on the Earth, you would weigh only 35 lb. on Mercury.

Mercury is the planet nearest to the Sun. It revolves around the Sun in an elliptical orbit at an everage distance of 36,000,000 miles. Since the path of Mercury lies within the orbit of the Earth, we never find it going very far away from the Sun—never more than 23°. This makes it very difficult for us to see it. But astronomers have been able to detect certain vague markings on its surface. These markings show that Mercury's one day (the time it takes to rotate once) is equal to about 88 days of our Earth. Since Mercury's one year (the time it takes to travel once round its orbit) is exactly the same, that is, 88 days, it is obvious that any part of this planet would face the Sun constantly for one half of the year, and would be turned away from the Sun for the other half of the year. The side facing the Sun must be a furnace giving out excessive heat, while the side away from the Sun must be excessively cold.

Every few years Mercury passes right across the face of the

Sun, and on such occasions it can be seen as a tiny black circle. Seen against the background of the Sun, it seems to possess neither any atmosphere nor any satellites.

Owing to its proximity to the Sun, Mercury may be visible to us only a little after sunset or a little before sunrise, with the result that many people have never even caught a glimpse of this planet. It is not surprising that the ancient Greeks regarded it as a god with winged feet.

Venus. The planet Venus is named after the goddess of beauty because it reflects the light of the Sun very strongly and thus appears to be the most brilliant of all the heavenly bodies. It is slightly smaller than the Earth in size, and maintains an average distance of 67 million miles from the Sun. It is not known whether daylight and darkness succeed one another on Venus in the same way as they do on the Earth or whether one half of the planet remains in perpetual light and the other half in perpetual darkness. We do know, however, that Venus completes one revolution round the Sun in 225 of our days and that its admosphere is very dense, containing a good deal of carbon dioxide but little oxygen or water vapour.

Mars. Compared to our Earth, Mars is about half in size, but it is nearly twice as far from the Sun as the Earth, with the result that its year is made up of 780 of our days and that it receives much less heat and light from the Sun than our Earth. The atmosphere of Mars is very thin and contains nitrogen and some carbon dioxide but no hydrogen or oxygen and, therefore, almost no water. Summer and winter on this planet are nearly twice as long as they are on our Earth. The temperatures on the surface of Mars must be very low, the average temperature being probably below zero, though during the long summer season it may rise above freezing point. We can guess that Mars must be a bleak world, but it is generally thought that in many respects the physical conditions on that planet resemble those on the Earth.

Mars is our closest neighbour and it is the only planet whose surface markings can be observed and studied by us in any detail. These surface markings are of considerable interest. They consist of large blue-green patches superimposed upon the general reddish background of the planet. In addition, there are a number of fine streaks. Certain astronomers hold the view that these streaks

could be canals or waterways but there is not much evidence to confirm this view. The surface features of Mars show two polar caps, which may be composed of snow, ice or hoar frost, and which behave in the same manner as the polar caps of our Earth—that is, they appear to be shrinking in summer and expanding during winter.

Some people have suggested that there is a strong possibility of the existence of life on Mars. But in the present state of our knowledge we can neither confirm nor refute this suggestion. All that we can say is that if there is life anywhere in the Solar System besides our planet, then Mars is the place where we should look for it. However, it is more likely that life on Mars consists only of stunted lichens and mosses, living miserably on an icy tundra.

Jupiter. Of all the planets of the Solar System, Jupiter is the largest—its equatorial diameter being eleven times that of the Earth. In fact, this planet contains more material than is contained in all the remaining eight planets of the Solar System. This material of Jupiter, however, seems to be in a gaseous form, for the considerably flattend shape of the planet suggests that it is a gaseous sphere.

When we turn our telescope towards Jupiter, we are able to see a number of strange markings on its surface. These markings consist of a complex system of dark and bright belts and spots which show rapid changes. The fact that these markings change rather rapidly proves that they are atmospheric phenomena—probably clouds of methane (marsh gas and ammonia condensed into snow-like crystals). The temperature at the upper surface of these clouds is estimated to be about 250°F., and that is what should be expected in the case of a planet so far away from the Sun. It is likely, however, that the surface of the planet may be a little warmer than the upper surface of its clouds, but the difference would not be much and one can be sure that Jupiter is no hospitable home for life as we know it.

Saturn. In every respect Saturn is a brother of Jupiter, although slightly smaller in size. It is a huge planet, being 750 times larger than our Earth. Like Jupiter it is enveloped in a blanket of clouds, so that we are never able to see its surface. Situated at a great distance from the Sun, it receives very little light and heat, and altogether it must be a very cold world.

Saturn is a notable planet in that there are no less than nine moons circling around it. No other planet, except Jupiter has so many moons. But the most remarkable phenomenon is the "rings" which are seen around this planet. It is now known that these rings are not continuous masses of matter but are composed of swarms of rock-like meteors revolving about the planet in its euatorial plane. The rings are of enormous circumference. From the inner edge of the innermost ring to the outer edge of the outermost is a distance of 41,500 miles. But these rings are quite thin, probably not more than 5 to 10 miles. About every 15 years Saturn's path brings it in such a position that its rings are presented edgeways to the Earth. On such occasions the rings of Saturn are found to be so thin that they can hardly be seen even through the most powerful telescope.

Uranus, Neptune and Pluto. The three outermost planets of the Solar System, Uranus, Neptune and Pluto — remain to be mentioned. The distances separating these planets from the Sun are tremendous. None of these planets was discovered until after the invention of the telescope. In fact, two of the three planets, namely, Neptune and Pluto, can never be seen with the naked eye. They receive very little heat and light from the Sun and we can assume that it is improbable that life could exist at such a low termperature and in such pitch darkness. But we cannot be certain, for although the clouds enveloping the planets may be icy cold, the surface of the planet may have volcanoes, hot springs or radioactivity, and these may be responsible for a warmer climate so that these planets may be like hot-houses.

Uranus was discovered by Herschel in 1781, Neptune by Galle in 1846, and Pluto by Tompaugh in 1930. The last named planet is the farthest from the Sun, the distance being 1675 million miles. It receives only 1/1600th as much solar heat and light as the Earth does. It travels at a rate of 3 miles per second and takes 248 years to make one revolution on its orbit.

Mercury, Venus and perhaps Pluto do not have any satellites (or moons). All the other planets possess moons which circle about them as our Moon does about the Earth. Mars has two moons which are very small, while Jupiter has twelve, Saturn has nine, Uranus has five and Neptune has two.

The nine planets and the thirty moons are admittedly the most

important members of the Sun's family, but they do not represent the whole family. There are certain minor members also. Scattered throughout the Solar System, there are millions upon millions of meteoric particles, which may be regarded as the raw material of the universe. These particles varying in size from bodies which we call satellites to minute specks of dust, may be classified into three distinct types: asteroids, comets and meteors.

Asteroids

It has already been mentioned that the Solar System is broadly divisible into two parts, namely, the inner dwarfs and the outer giants. Towards the close of the eighteenth century it was suggested on the basis of mathematical computations that there must exist an undiscovered planet in the gap between the inner dwarfs and outer giants. A search for the missing planet was started particularly with the help of photography, and as a result not one but several minor planets (or asteroids) were discovered. Until now no less than 2,000 asteroids have been discovered, and it is assumed that tens of thousands more exist. Most of the asteroids are found in the belt between the orbits of Mars and Jupiter, but a few odd ones have been found even outside this belt. All the asteroids follow the "rule of the road", that is to say they travel in the same direction as the planets. They are, however, very small, most of them having a diameter of no more than a few miles. The diameter of the largest asteroid (Ceres) is said to be only 490 miles.

We do not know anything of the circumstances in which asteroids were formed. Earlier theories assumed that asteroids were fragments of a disintegrated planet which once existed between Mars and Jupiter. Another theory considers them as *residual* material which was left over when the *primordial* matter gathered into planets and moons. Whatever be the truth about the origin of asteroids, this much we know for certain that no asteroid, not even the largest, possesses atmosphere. In all probability asteroids are nothing but barren lumps of rock.

Since Mars and Jupiter are closest to the belt of asteroids, they sometimes deflect the asteroids and even "capture" them and turn them into "moons". But the captured asteroids should be called

"satellites" rather than "moons" because while the moons are large spherical bodies revolving in a definite orbit for millions of years, the asteroids join the company of a planet only accidently and temporarily.

Comets

For a long time in the past, the appearance of a comet in the sky was regarded by the people as a bad omen presaging some great catastrophe. Large comets are indeed remarkable and awe-inspiring spectacles, some being so bright as to be visible even in broad daylight—their immense tails streaming half way across the dome of the sky and directed always away from the Sun. On an average, about five comets are discovered every year, but most of them are small, faint and tailless objects which can be seen only with the help of telescopes. Huge comets are of rare occurrence, so rare indeed that one should consider himself lucky if he is able to witness the passage of a great comet even once in a lifetime.

Comets are small heavenly bodies or loose collections of stones, dust and gas, travelling round the Sun in *elongated ellipses, parabolas* or *hyperbolas*. As a rule, the speed of a body revolving round the Sun increases as that body approaches the Sun and decreases when it moves away from it. Consequently, a comet does not travel with a uniform velocity and its speed is accelerated or slackened according to its distance from the Sun. Away from the Sun, it travels rather slowly, say at the rate of 10 miles per hour, but as it comes closer to the Sun, its speed becomes progressively greater until it becomes terrific.

In recent times, the last great comet which approached the Sun was Halley's Comet. It has been observed that this comet returns to the Sun every 75 years. In 1910, it remained visible to the naked eye for four and a half months, and it was calculated that its length then was some 28,000,000 miles.

Meteors and Meteorites

Meteors (or shooting stars) appear to us as stars breaking loose and falling down from the firmament. In Grandma's stories child-

ren are told that the shooting stars are devils running away from the fiery whip of angels. Actually, meteors or "shooting stars" are the embers of comets, and are created when minute particles of rocks and metal ore from cosmic space flare up while crossing the dense atmosphere of the Earth. Hurtling through the atmosphere at a speed of about 20 to 30 miles per second, the particles are heated to incandescence by the friction of the air. The friction is so great that all but the most massive lumps of material are completely vaporized long before reaching the Earth's surface. Meteors become visible to us only after they have reached within a hundred miles of the Earth, and most of them are burnt out while they are more than 30 miles above us.

Those meteors which survive their journey through the atmosphere and arrive at the surface of our planet are called meteorites. They may be described as stones from heaven. Thousands of meteorites have been collected from different parts of the world, and you can see some specimens in any good museum. The largest piece found so far is about 30 tons in weight. Since meteorites are bodies from Space falling on the Earth, it may be expected that the mass of our planet must increase by these constant additions. In fact, it has been calculated that every year about 4,500 tons of meteoric materials falls upon the Earth's surface. Yet indications are that despite the continual shower of meteorites, our Earth has not registered any appreciable increase in weight or size during the last 2,000 million years. This is because the meteoric addition is counter-balanced by the loss of material in the form of gases, dust and vapour that escapes from the upper layers of the atmosphere into cosmic space.

In composition, meteorites are not very different from the common ores or rocks which constitute our Earth. The age of a meteorite can be roughly determined on the basis of the radioactive elements contained in it, and scientists generally agree that no meteorite is less than 3 billion or more than 5 billion years old. Thus the age of meteorites confirms the calculation that the universe in which we live is about 3 to 5 billion years old.

CHAPTER TWO

THE MAKING OF THE EARTH

General Characteristics of the Earth

MILLIONS of years ago—perhaps 3,000 million years or more, there was a tremendous explosion in the universe. What exactly happened is not known, but it is possible that the Sun exploded and the debris (or wreckage) of this explosion was flung far and wide into Space. This debris eventually condensed into a number of large planets and countless smaller bodies.

Our Earth is one of the planets which was formed in that catastrophe, and in many respects it holds an intermediate position amongst its sister planets. Situated at a distance of about 93,000,000 miles from the Sun, it is the largest of the minor planets and has a diameter of about 8,000 miles, and a circumference of nearly 25,000 miles. It differs from all the other planets in one important respect, i.e., it possesses material which is denser than that in any other planet. The specific gravity of this material is 5½—that is to say, it is 5½ times as heavy as an equal volume of water. In contrast, Saturn, which is the lightest of the planets, has a specific gravity of only .75. As for the total mass of the Earth, it is calculated to be 6×10^{21}, or 6,000,000,000,000,000,-000,000 tons.

One of the most important facts about the Earth is that it is a sphere, although the spherical shape is not quite perfect. Owing to the centrifugal force created by its own rotation and also because of the attraction exerted upon it by the Sun and the Moon, the Earth bulges at the Equator. Hence, the equatorial diameter, which is 7,926½ miles, is 26½ miles greater than the diameter through the poles. In other words, while the equatorial circumference is 24,902 miles, the polar circumference is 24,861 miles. This difference in circumferences results in a difference in gravity. Hence, if you travel from one of the Poles to the Equator you would lose about one pound of your weight because you would get away a little farther from the centre of the Earth—from the centre of gravity.

The first attempt to calculate the circumference of the Earth was made in Egypt in about 235 B.C. The man who made this attempt was Eratosthenes, librarian at the great museum at Alexandria. He calculated that if the Earth were spherical, it should be possible to calculate its circumference by measuring the distance of one degree and then multiplying it by 360, for there are 360 degrees in a circle. Eratosthenes set about it by recording and comparing the length of the shadow cast at noon by a staff at Alexandria with a shadow cast by an equally long staff at Luxor. Then, by taking into consideration the distance between these two places, he arrived at the conclusion that the circumference of the Earth must be 28,750 miles. There was an error of about 15 per cent in this calculation, but it was not because of any mistake in the computation itself but rather due to the fact that the actual distance between Alexandria and Luxor is nearly 5 furlongs greater than was officially accepted at that time.

Shape of the Earth

As casual observers we do not bother much about the shape of the Earth. To us the Earth appears to be flat, and if we believe that it is a sphere, it is generally because we have been taught and told that it is so. Let us examine some of the evidences which support the idea that the Earth is spherical in shape.

One of the earliest proofs of the curvature of the Earth was given by Galileo, who pointed out that the shadow of the Earth as seen upon the Moon during a lunar eclipse (when the Earth is between the Sun and the Moon) is essentially circular. Since the shadow is circular, the object must also be circular.

Many proofs of the curvature of the Earth's surface are available now. Of these the one which is frequently given is that a ship which is approaching a shore appears only gradually. What happens is that at first only the funnel and the masts of the ship are visible and after some time the whole ship can be seen. Had the Earth been flat, the whole ship would have become visible all at once—of course, dimly at first and clearly later—nevertheless all at once.

It is said that the proof of the pudding is in the eating—so that no proof of the curvature of the Earth can be more convinc-

ing than an actual round-the-world flight in an aeroplane. Nowadays all that we need to do for observing the sphericity of the Earth is to buy a ticket from an air-line. In fact, we live in an age in which it is possible not only to see, but to photograph and measure the curvature of the Earth from the air.

The curvature of the Earth's surface, even though it may not be quite visible to us at ground level, is of great importance. It is the spherical shape of the Earth which is responsible for causing different types of climate. Also, it is this round shape which accounts for the fact that maps of large areas of the Earth cannot be made on flat surfaces, for it is a mathematical law that a spherical surface cannot be converted into a flat surface without considerable distortion.

Motions of the Earth

We know that the Earth turns steadily each day on an axis at the one end of which is the North Pole and at the other the South Pole. This motion is called rotation. While rotating on its axis, the Earth also advances at an average rate of 67,000 miles per hour on a gigantic annual path around the sun. This motion is called revolution.

The fact that night and day follow each other in regular succession is due to the fact that the Earth rotates. As our Earth turns on its axis from west to east, each part of its surface comes into the sunlight for a certain period and then turns away from it. The time which the Earth takes to make one rotation is approximately 24 hours. Thus, from one sunrise to the next we have a period of one day and one night. This time is divided into hours, minutes and seconds. The rotation of the Earth affects everything on its surface. The centrifugal force generated by this rotation pushes the waters toward the Equator and raises the level of the seas; the continents, too, floating on an underground sea of magma (pasty crude mixture of mineral or organic matters) drift towards the Equator; the ocean currents change their direction; the tides are distracted; the Trade Winds blowing towards the Equator are deflected.

As noted already, the movement of the Earth on the path which is called its orbit is described as "revolution". The Earth com-

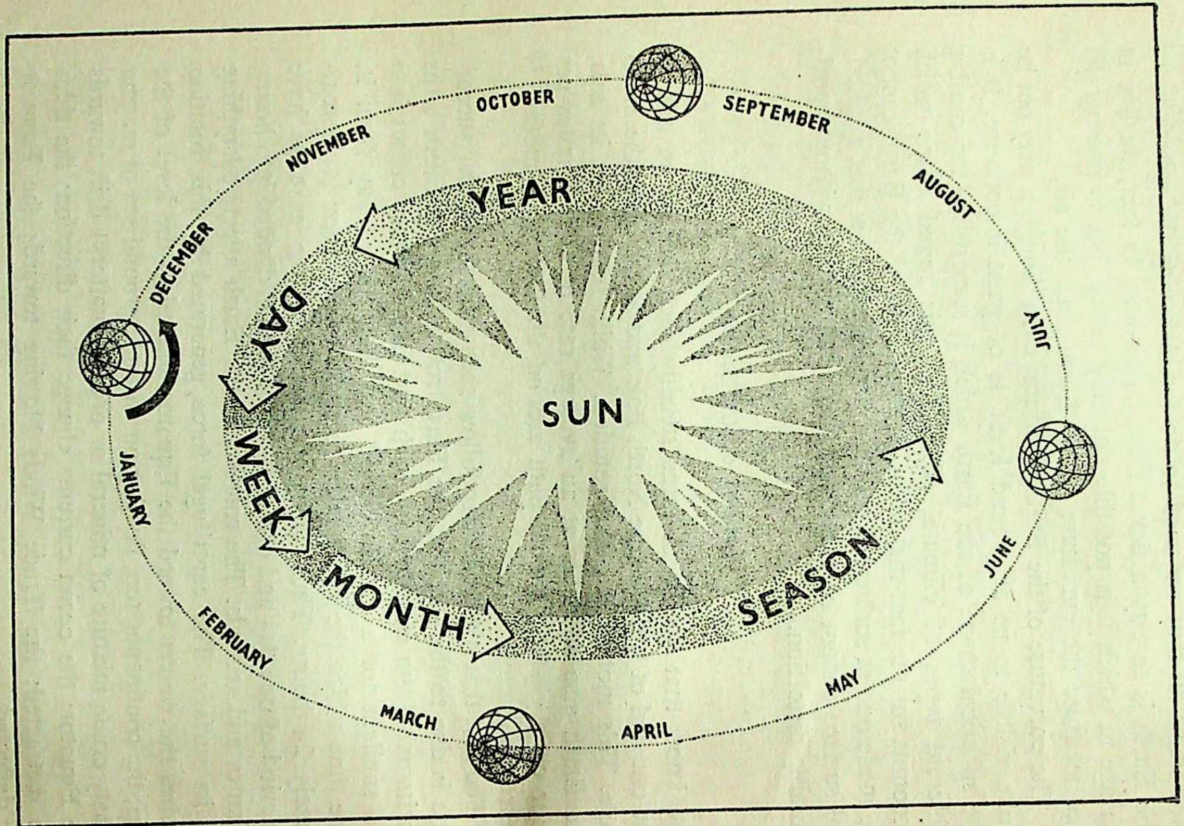

Fig. 4—EARTH'S ROTATION AND REVOLUTION

pletes one revolution in approximately 365¼ days, and it is this movement which causes the rhythm of the seasons. The ancient people did not understand the cause of change of seasons, but they did associate high temperatures with summer when the Sun rose high in the heavens at midday, and low temperatures with winter when the Sun was lower at noon. But nowadays we know for certain that long summer days together with the more powerful direct rays of the Sun are due to the fact that the Earth's axis is inclined at an angle of 66½° to the plane in which the Earth revolves round the Sun.

On the 21st of March and the 23rd of September, when the Sun's rays reach both the Poles of the Earth, days and nights are of equal length throughout the world. These days are called the equinoxes (aeques = equal; nox = night).

From the 21st of March, when the midday sun is overhead at the Equator, the Sun seems to shift its position northwards, until on the 21st of June it appears to be standing still over latitude 23½° N. before it moves southwards again. In the Northern Hemisphere this period of standing still is called the Summer Solstice (sol=sun; statum=to make to stand). The latitude of 23½° N. is called the Tropic of Cancer (tropic = turning point). Similarly, the Sun appears to be standing still over 23½° S. (Tropic of Capricorn) on the 21st of December, before it moves northwards again.

In addition to the two motions of the Earth (rotation and revolution), there is also a third motion which we call the wobbling (unsteady movement from side to side) of the Earth's axis. All these three motions can be illustrated by a spinning top—firstly, the spinning of the top on its pivot corresponds to the daily rotation of the Earth on its axis; secondly, the top revolves in wide circles, corresponding to the annual revolution of the Earth round the Sun. Finally, the swaying of the top's axis, which constantly changes its angle to the ground, corresponds to the wobbling of the Earth's axis. Astronomers have suggested that one wobbling circuit of the Earth's axis is completed in 26,000 years. This is the reason why the Pole star is gradually, although imperceptibly, shifting its position. This shifting will go on but we may expect that the star would return to its present position after 26,000 years.

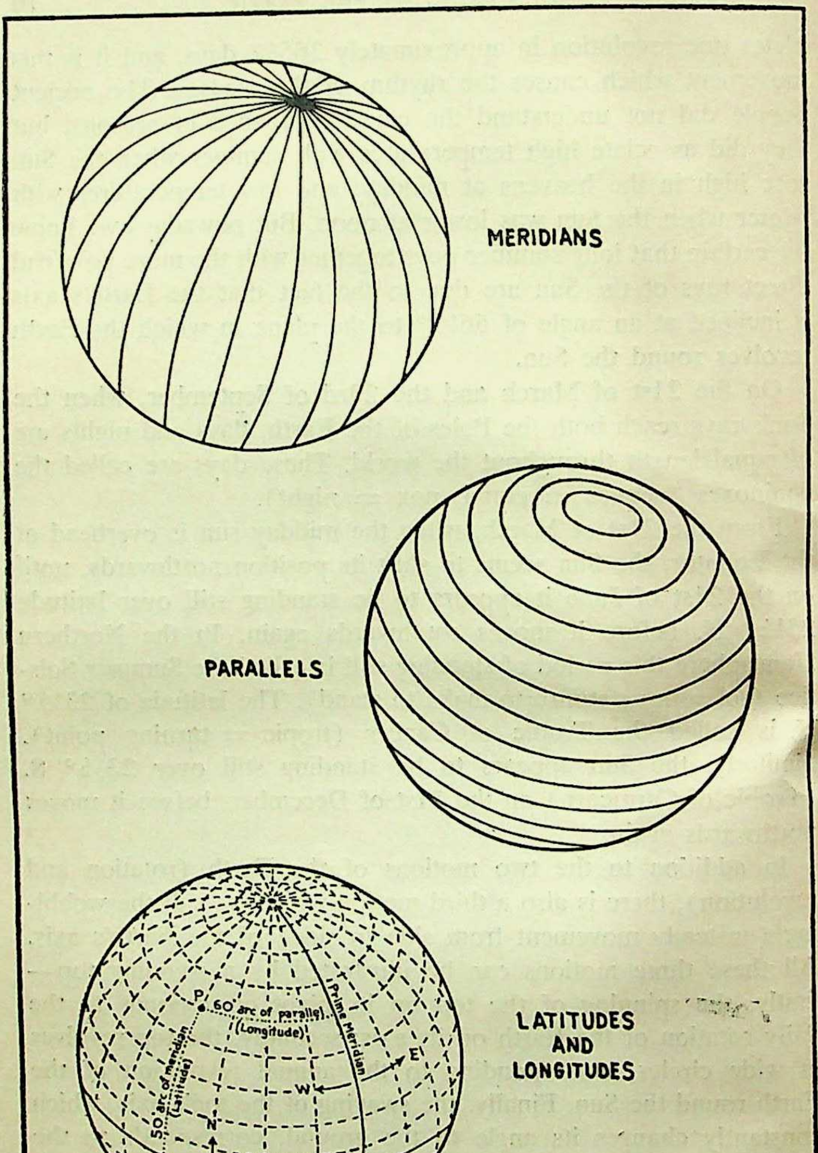

Fig. 5—LATITUDES AND LONGITUDES

Latitudes and Longitudes

The axis on which the Earth rotates is an imaginary straight line passing through the centre of the Earth and joining the North Pole with the South Pole. The Equator of the Earth is another imaginary line drawn completely round the Earth in such a way that at all points it lies exactly half-way between the North Pole and the South Pole. It is not difficult to see that the Equator divides the Earth into two equal parts.

To indicate accurately the position of places on the surface of the Earth, geographers imagine the globe to be covered with a network of lines at regular distances. Those running east and west and forming circles parallel to the Equator are called "parallels" and the distance between them is measured in "degrees of latitude".

Although latitudes represent angular distances, they can readily be converted into distances in miles if the size of the globe is known. Thus, the length of one degree of latitude is always about 69 miles.

The Equator represents the zero degree latitude, so that the latitudes of the Northern Hemisphere are "north latitudes", while those of the Southern Hemisphere are "south latitudes". Since the distance from the Equator to either of the Poles is one-fourth of a circle round the Earth, it will measure ¼ of 360 degrees (= 90°). Thus 90° north latitude marks the North Pole and 90° south latitude marks the South Pole.

To fix the position of a place, however, it is necessary to know something more than the latitude of that place. You can see, for example, that Hyderabad (in Sind) and Allahabad (in Uttar Pradesh) are situated on about the same latitude (i.e., about 25° 25′ N.). Now, in order to locate them more precisely we must find out how far east or west are these places from a given line of reference running from north to south (or from the North Pole to the South Pole). Such lines of reference are called meridians, and the distances between them is measured in "degrees of longitude". In terms of mileage, one degree of longitude has essentially the same length only at the Equator. Elsewhere the length decreases steadily until it becomes nothing at the Poles, where all the meridians meet.

In numbering the meridians, all countries agree that the count should begin from that meridian which passes through Greenwich, that is the location of the British Royal Observatory (estabolished in 1675). This meridian is known as the Prime Meridian, and it is from this meridian that we count 180 degrees eastward as well as 180 degrees westward. As you can readily see, the position of a place on the globe can be exactly fixed if its latitude and longitude are known, because then that place must be at the intersection of two lines. Thus, you can locate Hyderabad (Sind) at 25° 25′ N. lat. and 68° 38′ E. long., and Allahabad at 25° 28′ N. lat. and 81° 54′ E. long.

Latitudes and longitudes are of great use, and a good example of their usefulness is the way in which they enable ships and aeroplanes to determine their exact position. In fact, many lives have been saved because ships and aeroplanes have been able to tell the exact place where an accidnet has occurred. In 1912, for instance, the ship *Titanic* which had run into an iceberg sent a wireless message that it was struggling in 41° 46′ N. latitude and 50° 14′ W. longitude. All the ships which received this message rushed to the spot and were able to save 711 lives on board the *Titanic*.

The determination of latitude as well as longitude depends on astronomical observations. The latitude of a place can be determined by observing the Sun's atltitude at noon at that place. On the equinoxes the Sun is in the zenith (vertically overhead) at the Equator and its altitude is 90°. Between the zenith and the horizon there are 90° and the difference between this figure and the figure for the altitude of the Sun is 0° (90 – 90 = 9). Hence, the latitude of the Equator is 0°. Now take Delhi as another example. Here, at the equinoxes the Sun's altitude at noon is 61½°, so that the latitude of this place should be (90° – 61½°=28½°). On those days of the year which do not fall on the equinoxes, the exact declination of the Sun should be taken into account. For ready reference, the Sun's declination of any particular day is given in a book called the *Nautical Almanac*.

The latitude of a ship at sea is fixed by observing the midday altitude of the Sun with a *sextant*. In the Northern Hemisphere latitude can be found at night from the altitude of the Pole Star which is approximately above the North Pole (90° N. lat.).

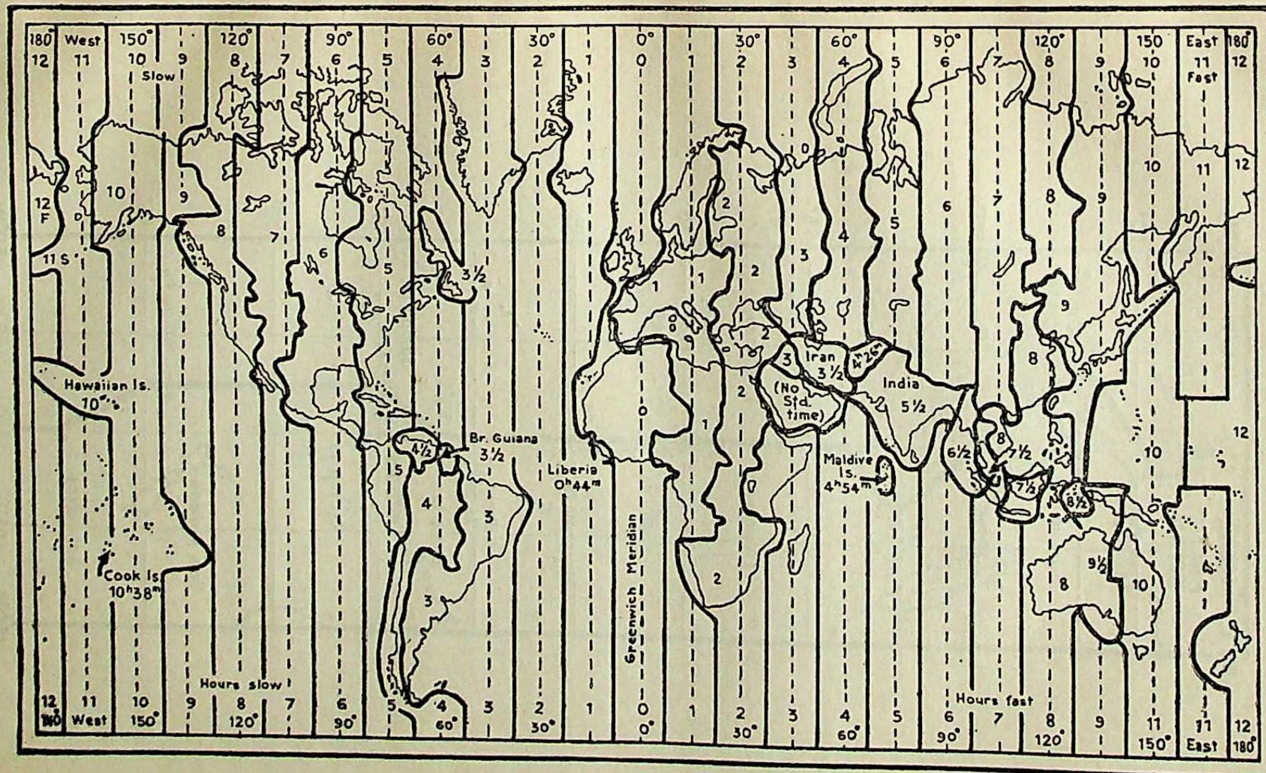

Fig. 6—TIME-ZONE MAP OF THE WORLD

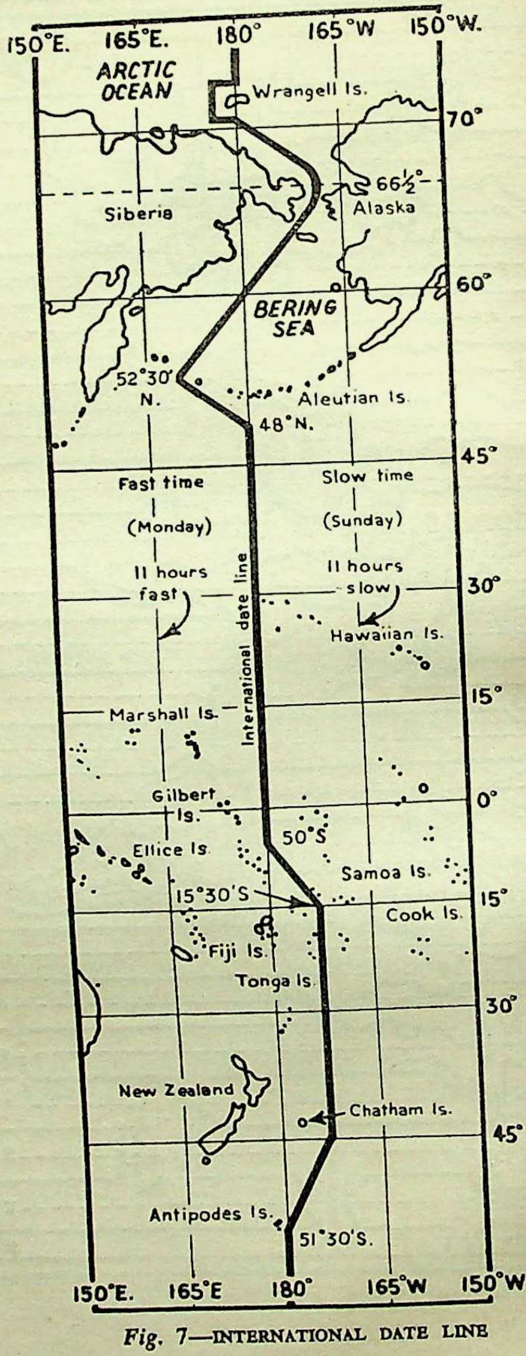

Fig. 7—INTERNATIONAL DATE LINE

As far as the reckoning of longitude is concerned, the easiest method is to compute it by noting the difference in the two kinds of time, one given by the observation of the Sun at noon and the other given by a *chronometer* or a watch which is set to the Greenwich time.

Longitude and Time

Can you imagine all the difficulties which we would encounter if we had no such things as years, months and days, and the division of day and night into hours, minutes and seconds? Years, months, days and hours mark the progress of time, and the best means of measuring time is the movement of the Earth, the Moon, and the planets.

The Sun regularly rises and sets every day and naturally it is the best time-keeper throughout the world. Even in ancient times people reckoned the "local" time on the basis of the length of the shadow cast by the Sun, which is the shortest at noon and the longest at sunrise and sunset.

It can be seen that since the Earth rotates on its axis from west to east, those places which are east of Greenwich must be ahead of time (mean solar time) and those to the west must be behind time. The rate of difference can be calculated, for the Earth rotates through 360° in 24 hours, which means 15° in one hour, or 1° in four minutes.

Hence, if we know the difference in time between two places and the longitude of one of them, we can easily discover the longitude of the other place. If, for example, it is noon at Greenwich what is the longitude of Baghdad where it is 3 p.m.? Since the difference in time is 3 hours, the longitude of Baghdad should be 3 x 150 = 450, and since Baghdad is ahead of Greenwich in time, its longitude must be 45° East.

It is obvious that if every place was to keep its own "local" time, it would cause great inconvenience. For example, the rail and road services would be completely disorganized. Hence, in order to avoid confusion and chaos, the majority of civilized countries have established time zones which are roughly 15° wide. Throughout each zone the same time, known as the *standard time,*

is observed. The time in each belt varies by exactly one hour from the time in the belts on either side.

Thus, the time zone system round the Earth means that when on a certain date, say April 15, it is noon at Greenwich it is only 7 a.m. in Washington and midnight in Samoa. In other words, while it is noon at Greenwich it is the early morning of April 15 in Samoa. As far as places to the east of Greenwich are concerned, it will be 2 p.m. in Leningrad, 5.30 p.m. in India and 11 p.m. in the Fiji Islands. Now, any map will show you that Samoa and Fiji Islands are quite close to each other, but there is a line between them which is called the *International Date Line,* on the one side of which April 15 would be just beginning, while on the other side of the line April 15 would be just ending. Thus if a ship which is sailing westward crosses the line it will lose a day, but if a ship which is sailing eastward crosses the line it will gain a day. The famous explorer Magellan was tricked by this "loss" of a day. In 1519 he left Spain to make the first voyage round the world. When he returned to Spain after three years he could not understand why according to his log book the date was September 6, while the people at home said it was September 7.

CHAPTER THREE

THE ORIGIN OF THE EARTH

Pre-scientific Ideas

MEN of olden days must have wondered how the world had come to be as they found it, and how the Sun, the Moon and the stars moved in their regular courses. Since scientific explanations were out of their reach, they invented fascinating stories to explain these things. These stories were about beings or gods who in appearance were like human beings, but much bigger in size and far more powerful. According to some of these stories or myths, one of the gods originally created man and taught him what to eat and how to use fire and other useful things.

Similar myths were invented by almost all the ancient civilizations. For instance, the *Iroquois* Indians of North America believed that a heavenly woman was somehow tossed out of the void, so that she fell upon a turtle. Later, the turtle became the Earth and the woman was transformed into the sky which is bent over the Earth. Similarly, the Greeks made up some of the most beautiful stories about the creation of the Earth.

The ancient Greeks believed that long, long ago—in the beginning of things—all was chaos. Gradually, out of this chaos certain objects began to take shape. First appeared the Sky and the Earth, whom the Greeks called Uranus and Gaea. Uranus assumed the rulership of the world and took Gaea as his wife. The couple produced many children, amongst whom were twelve huge Titans as well as three terrible creatures called Cyclops, each of whom had only one eye, and two very strong brothers each with a hundred hands and fifty heads. Uranus detested his children so much that he threw them into Tartarus, i.e., the vast abyss below the Earth. This naturally made Gaea very angry and she ordered the twelve Titans to punish their father. The Titans rose against their father and destroyed him, and one of them whose name was Cronos made himself the ruler of the world.

The ancient Scandinavian myth, like that of the Greeks, says that the Earth was born out of darkness and disorder. According

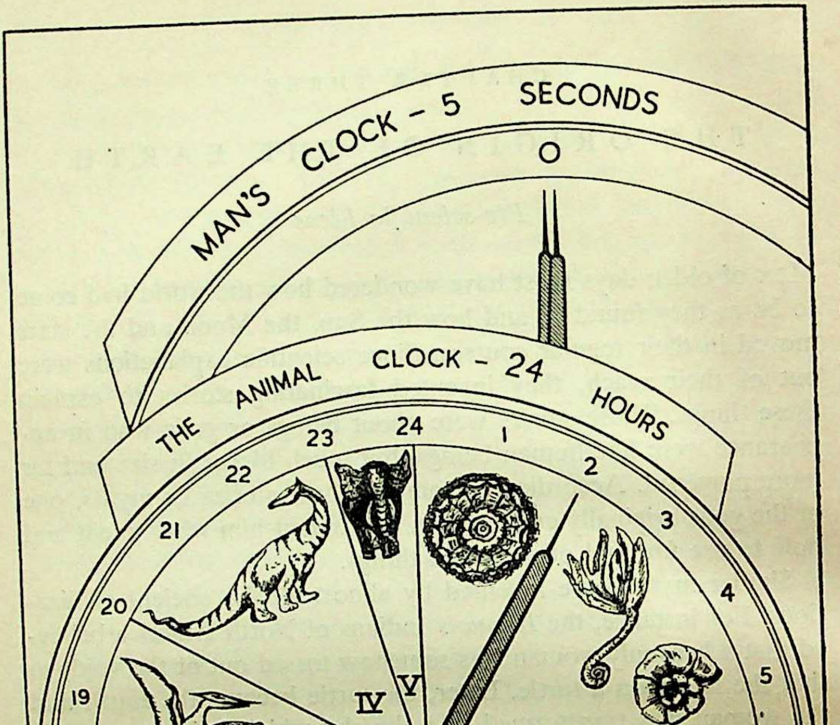

Fig. 8—THE CLOCK OF LIFE-ON-THE-EARTH—If the period of the development of life on the earth is taken as a 24-hour day, the history of the mammals would occupy only one hour, and that of man would occupy only the last few seconds.

to this myth, there existed in the beginning two worlds, one of mist and another of light with a bottomless deep in between them. From the world of mist there flowed twelve rivers whose waters gradually filled up the deep. Then from the world of light came warm winds which melted the ice, producing vapours which formed clouds. These clouds gave birth to the giant Ymir and his children. The next to appear was Bori, who was a very handsome and powerful god. Bori married a daughter of the giants who gave birth to Odin, Vili and Ve. These three slew Ymir and from his body and blood they made the Earth and the Heaven.

In the Hindu mythology the story of creation begins with the occurrence of a great flood in the *Pralay Kaal* (the most ancient times). Then Brahma, the creator, asked Varaha (the pig-god) to dive in the flood and scoop out some mud. It was out of this mud that the Earth was created.

According to the Old Testament, God created the world in six days and on the seventh day He rested. This belief was held by the church for a long time. It is amusing to think that as recently as in 1654, Archbishop Ussher of Armagh declared categorically that the world was created at 9 o'clock on the morning of October 26, in the year 4004 before Christ. What a precise calculation!

Early Scientific Ideas

As a matter of fact, so long as men believed that the Earth had a special position in the Universe, it was impossible for them to advance any scientific explanation of its origin. The problem of the birth of the Earth could not be understood without an understanding of the nature of the Solar System and the Universe, for the earth is only a tiny part of the Solar System and the Universe.

First of all we should try to calculate just how old the Earth is. From the evidences available, it seems certain that the age of the Earth is more than 3,000 million but less than 5,000 million years. Now, such a long period of time is beyond the comprehension of human mind. If we suppose the age of the Earth to be only 10 days, then the period of the entire development of life on the Earth would be the last 24 hours, the history of mamals would be only the last one hour, and that of man would be only the last 5 seconds. The fossils of the oldest animals date far back in pre-

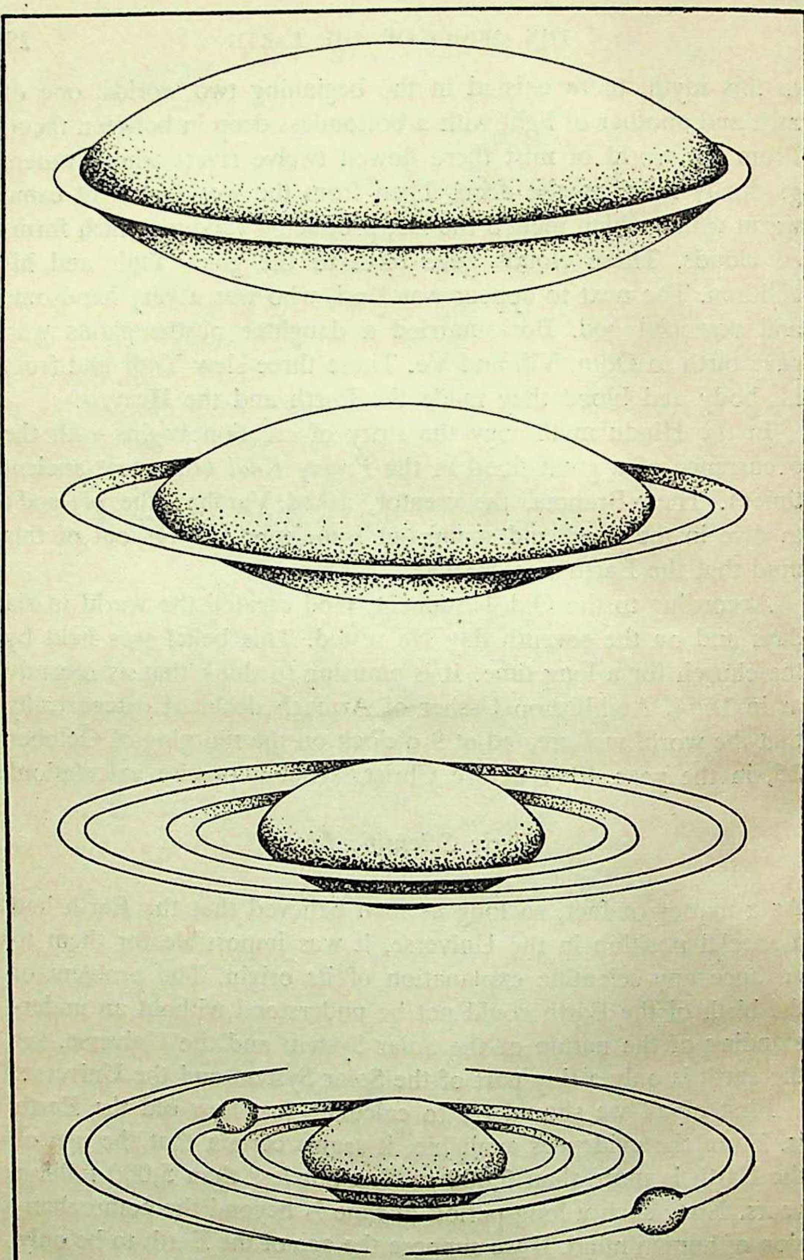

Fig. 9—LAPLACE'S HYPOTHESIS OF PLANETARY FORMATION—The hot, spinning nebula cools down and contracts and sheds rings of matter which become planets.

history, but you can see that even they tell us only about the more recent events in the Earth's life-story.

No one witnessed the birth of the Earth, but there is one clock which started ticking at the time of its birth and which still continues to tick. That clock is uranium—a substance which is radioactive and which decays gradually so that in a certain period of time it turns into lead. The lead formed by radioactive matter can be distinguished from the ordinary lead, so that by examining a uranium-lead we can ascertain its age. While we have no way of knowing when a certain body of uranium was created, we do have the means to ascertain how long a given deposit of uranium has been lying where it is at present found. Now, the uranium in our oldest rocks is found to be about 2,000 to 3,000 million years old—which roughly speaking should be the age of the Earth.

Having learnt about the age of the Earth, we can safely assume that the planets of the Solar System were formed either from the Sun itself or from a star similar to the Sun and from a cloud of diffuse matter around the Sun. What was the actual process of formation? Well, this is a rather difficult question. So far, about a dozen theories have been advanced to explain this but none has been found to be wholly satisfactory.

The earliest rational attempts to explain the origin of the Solar System were made by philosophers,[1] amongst whom may be mentioned Kant, Swedenborg and Wright. Of all the philosophical theories, that of Kant is the best known. In 1755, this philosopher published a book entitled *Natural History of the Heavens* in which he pictured primordial matter which was in a chaotic condition, but which later condensed into spinning nebulae (or vast gas clouds, disc-shaped and in a low rotation). Kant identified one of these nebulae with the Sun and suggested that this nebulae shed masses of gas which on solidification turned into planets.

Laplace, a French mathematician advanced similar ideas but approached the problem mathematically. According to Laplace's theory, which is generally known as the Nebular Hypothesis, there was a hot and spinning nebula which gradually cooled down so that the heat radiated by it escaped into Space. The cooling process resulted in the contraction of the nebula, and with continued

[1] For a philosophical discussion on the subject, refer to *Man. Reality and Values,* a publication of the General Education Reading Material Project.

shrinking, the nebula's rate of rotation progressively increased. Since a rotating mass of gas must as a rule flatten out, the nebula was flattened to such an extent that the centrifugal force at its edge became equal to the gravitational pull there. At this stage a ring of matter broke away from the main mass and gradually condensed into a planet. As the main mass further contracted, a second ring broke off and in due course condensed into another planet. This process of breaking away and condensation was repeated a number of times, resulting in the birth of a number of planets. You can readily see that according to this theory the outermost planets must be the oldest, and that Mercury, which is the planet closest to the Sun, must be the youngest member of the Sun's family.

In general, Laplace's theory seems quite plausible, but it has been subjected to severe criticism on several grounds. The first objection is that the Solar System does not contain enough atoms which may account for the formation of huge gases in the sphere extending from the Sun to the orbit of the outermost planet. Secondly, it can be shown mathematically that the material shed by the shrinking nebula could not form separate rings and, in any case, such rings could never condense into planets. Thirdly, it is difficult to see how the large planets, Jupiter and Saturn, rotating 50 times as rapidly as the Sun, could have derived their fast motion from the Sun. All these objections are valid, but even if these and other minor objections are ignored, Laplace's theory must fall when subjected to the mathematical principle of "angular momentum". The angular momentum of one body revolving round another is obtained by multiplying its mass with its distance and its velocity, and it is a fundamental principle that angular momentum can be transferred but never destroyed. At present, almost all the angular momentum of the Solar System is concentrated in the four giant planets (Jupiter, Saturn, Uranus and Neptune), whereas if Laplace's ideas were correct, we should expect to find most of the angular momentum in the Sun itself.

In the days of Kant, a scientist whose name was Buffon, put forward a suggestion that the Solar System was formed as a result of the disruption of the Sun by another heavenly body. The disruption was caused by gravitational attraction which produced a tidal wave in the Sun and detached a string of planets from it. The Tidal

Wave theory was rejected by Laplace but later on it was revived several times by one scientist after another.

The first methodical presentation of the Tidal Wave theory came in 1900. It was presented by two American scientists, Chamberlin and Moulton. These scientists agreed that Space is essentially empty and that the distances between stars are immense. The distances are so enormous indeed that if three neighbouring stars were to be represented by cricket balls, the balls should be placed at places as distant as Delhi, Calcutta and Bombay in order to make a model of the empty Universe. The possibility of encounter between two stars, however, remains. Now, if we assume that in the very distant past a star came close to the Sun, we can imagine massive tides rising upon that star as well as upon the Sun. As an upshot, a large quantity of matter may have been torn away from the Sun and sent spirally round it.

Having done its work, the wandering star moved away into the Space, leaving the Sun surrounded by a cloud of debris. This cloud slowly cooled down and solidified into small particles or "planetesimals." Here and there the planetesimals aggregated, and some of the aggregations became large enough to collect other planetesimals by gravitational attraction. Gradually, almost all the planetesimals were collected into a few large lumps, the final result being the establishment of a system of planets around the Sun.

It is suggested that once an aggregation of planetesimals grew as large as about a hundred miles in diameter, its gravitational pull became strong enough to attract a lot of planetesimals, enabling it to grow comparatively quickly into a body of planetary dimensions. This sounds all right, but it is difficult to see how under the conditions assumed by Chamberlin and Moulton any initial aggregation could ever reach such a size (say 100 miles in diameter) which could rapidly attract the planetesimals.

Modern Ideas

This difficulty was recognized by James Jeans who put forward a modified Tidal Theory. Jeans postulated that the passing star, instead of producing a "debris of cloud", tore off from the Sun a cigar-shaped filament, which on condensation produced planets. An attractive feature of this theory is that the largest planets

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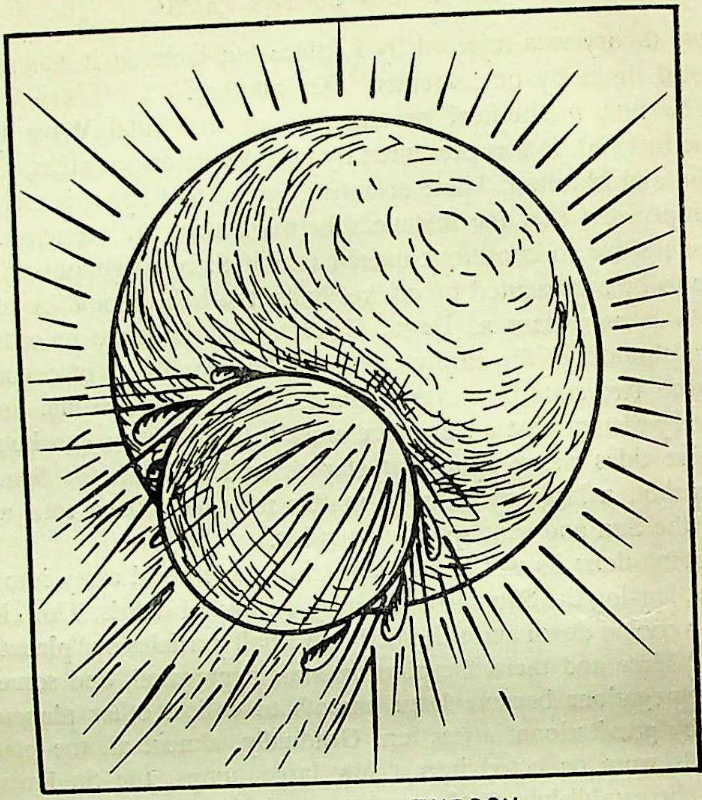
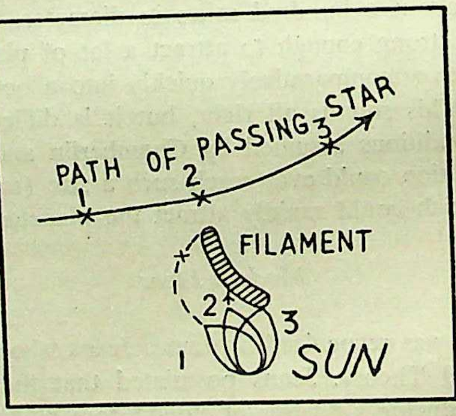


COLLISION THEORY



TIDAL THEORY

Fig. 10—ORIGIN OF THE EARTH

(Jupiter and Saturn) are found, as should be expected, in the middle of the "cigar", and the smaller planets are situated at the tapering ends. According to this theory, the satellites were formed by a similar process, this time the Sun playing the role of the passing star.

The theory had a number of loop-holes, and the various mathematical difficulties which it presented led Harold Jeffreys to suggest that the passing star did not just pull the Sun but actually gave a glancing blow to it. Even this modification failed to meet all the criticisms made against the Tidal Theory. The problem of the distribution of augular momentum, for example, remained unsolved. Above all, the composition of the Sun is such that it lends little justification to any of the Tidal Theories.

To understand the composition of the Sun we must note that while the surface temperature of this body is about 6,000° C., the temperature at its centre is about 20,000,000° C. The hot gases inside the Sun are locked in it, and the crushing pressure of the outer layers of the Sun does not allow these gases to expand and escape. Now, if we assume that a substantial portion of the Sun was torn off, as is assumed in the Tidal Theory, this must have released the pressure from the Sun's interior and the gases would have expanded with a violence that would have rendered the whole planet-building process quite impossible.

One of the contemporary theories on the origin of the Solar System is that which takes into account the fact that almost half the stars in the universe are *binaries* (i.e., double stars associated with each other and revolving round a common centre of gravity). Now, we can assume that formerly our Sun was one component of a binary pair. This binary pair, according to Russell and Lytleton, was disrupted by the intruding star which struck the Sun's companion and thus produced considerable amount of debris or broken pieces that led to the formation of planets. Of the several variations of the Binary Theory which have been advanced in recent years, the most interesting is that presented by F. Hoyle, who has suggested that the intrusion of a third star is not necessary to explain the disruption of a double star system. He reminds us that double stars are not identical twins, but are of different types and temperatures. As a rule, the hotter of the two stars builds up larger atoms and consequently becomes heavier. Its

internal heat creates such a strong radiation that the star finally explodes. Such explosions are known as *supernovae* and can be seen from distances of millions of light years. In a supernova explosion, most of the star's material is hurled out into Space at a speed of millions of miles per hour. The energy released in such an explosion must indeed be enormous.

As far as the formation of our planetary system is concerned, it has been suggested by Hoyle that the companion of the Sun exploded and during the last stages of its outburst—when its material went down hurtling in Space—it ejected a cloud of gas. This cloud was captured and retained by the Sun, and it was out of this cloud that the planets condensed in much the same way as was formerly suggested by Chamberlin and Moulton in their Planetesimal Theory.

Hoyle's theory answers a number of questions which the other theories have failed to solve. It explains, for example, how the planets can rotate at a speed greater than that of the Sun and how they can contain atoms which are heavier than those found in the Sun. According to this theory, the Sun is not the "mother" of the Earth but rather its aunt. The mother died while giving birth to the planets including the Earth, and ever since her children have been living under the command of their aunt.

In recent years an entirely different theory has been postulated by a German astrophysicist, C. F. Von Weizacker. According to this theory, gas is found everywhere in Space, but generally its density is very, very low. However, denser gas clouds do exist here and there, and it is possible that the Sun passed through one such cloud and was wrapped up in an extensive gaseous envelope. The cloud cover around the Sun must have extended farther than the present orbit of Pluto which is the outermost planet. The collisions and frictions of the particles of gas-cloud resulted in the formation of circular, disc-shaped shells which gradually became more and more massive until they turned into planets.

The problem of the orgin of the planetary system is a matter of scientific speculation (thinking and guessing). Whatever may be the mode of the origin of our planet and howsoever insignificant its position in the universe, the Earth is our beautiful home. Its blue oceans and green fields, its snow-capped mountains and flowering meadows, its winds and clouds, its towns and cities, its

multitudinous species of plants and animals make it a very attractive place for us.

What is the future of our planet? How long is it going to last? Scientists tell us that the Sun is gradually becoming hotter, and a time may come when its heat will become so intense that it will scorch and burn everything on the Earth. The blazing Sun will then cause our oceans to evaporate and our atmosphere to escape into the Space. Deprived of all its water and air, the Earth will become a glowing ball of fire.

But that day of doom and destruction is far off, and it won't come for thousands and millions of years. In fact, our present age is only the fresh glorious dawn of the Earth's history and a whole sunny and bright day stretches before mankind in which it can make the world a better place to live in. Alternatively, mankind has the choice to destroy itself with a Hydrogen bomb or similar weapons. Let us hope that it is not going to be a mad man's choice.

The Interior of the Earth

First of all, let us admit the fact that we know very little about the interior of the Earth. Of course many books of geography contain pictures which show that the Earth consists of a hard core or centre which is surrounded by concentric shells. All these pictures, however, are based on conjectures and the truth is that we have very little knowledge of the structure of the Earth. Men have been drilling the Earth for oil and other mineral resources but the greatest depth ever reached by a drill is five miles. This is an insignificant figure, considering that the centre of the Earth is about 3,650 miles from the crust.

Experiences gathered from mines and borings clearly indicate that pressure and heat increase as we penetrate downward into the Earth. The rate at which the temperature increases is 1° F. for every 60 feet. At this rate, extremely high temperatures should be met within a short distance of the surface. We can further conclude that due to exceptionally high temperature the central part of the Earth must be in a molten condition. There is, however, scientific evidence to prove that this is not so and that the core of the Earth is not molten but rigid.

Such scientific evidence is mainly provided by the shock waves of earthquakes. The earthquake waves travel in all directions from the centre of their origin. Some travel directly to the surface; others go towards the centre and return like an echo; still others undulate beneath the crust of the Earth. These waves tell us a good deal about the internal structure of our globe. They reveal that the Earth's internal mass is not uniform and that its density does not increase gradually towards the centre.

The core of the Earth is nearly 800 miles in radius and has a density 8 to 12 times that of water. This core is known as *barysphere* (baro = weight). Its high density indicates that it consists of heavy metals such as iron and nickel. It is more likely however that it is made of gas so highly compressed that it possesses the properties of a rigid metal.

The barysphere is surrounded by *mesosphere* (meso = middle), which has a density of about 6 and a thickness of about 2,100 miles. Surrounding the mesosphere is the *lithosphere* (litho = stone), or the stony crust of the Earth, which is some 700 miles in thickness. There is no doubt that the lower layers of the lithosphere with a density of 4 must be very hot but since they lie under the heavy pressure exerted by the solid crust above, they are probably in a plastic rather than molten condition. Whenever this pressure is even slightly removed the material turns into a molten state and in the shape of lava tries to escape to the surface of the Earth. The outermost zone of the Earth is the "rocky crust" which has a density of 2.7; its thickness is only about 15 miles.

It is this solidified outer crust of the Earth which supports all life. It forms the stage on which the drama of all human activity and civilization is enacted. Yet, how thin, delicate and flimsy is this crust! If you think of the Earth as an egg whose shell has been carefully removed, then the thin and flimsy membrane which is found under the shell will represent the solid outer layers of the Earth's crust, the white of the egg will represent the mesosphere, and the yolk its core (or barysphere).

Rocks and Minerals

The crust of the Earth is largely composed of rocks and minerals.

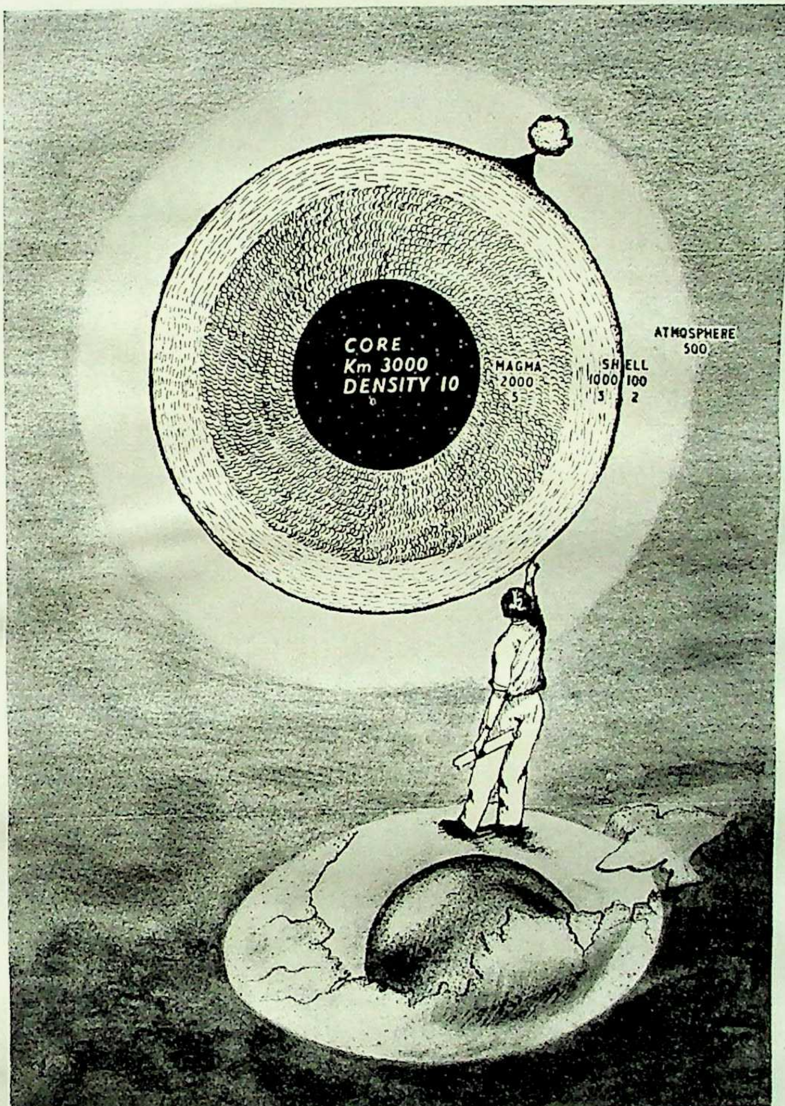


Fig. 11—WE LIVE ON THE MEMBRANE OF AN EGG—It is the thin, solidified crust of the earth which supports all life.

The science of rocks is called petrology and the science of minerals is called mineralogy.

The word "rock", as used by geologists, is rather difficult to define. In general, however, we may say that rocks are the naturally occurring substances which make up the crust of the Earth. Rocks are differentiated by different names, but the chemical composition of any one type of rock is far from constant, and two pieces of the same type of rock collected from the same locality may show considerable variations in composition. Let us understand that most rocks are made up of a mixture of "minerals". Just as a brick-wall consists of individual units or bricks, in the same way a piece of rock is built up of comparatively simple substances called minerals. A mineral may be described as "a simple substance" because it shows a constant chemical composition which can be expressed by a formula.

In earlier days, it was thought that every substance which was not organic (living organism) was inorganic and was described as mineral. Thus, rocks, soils and water all were classed as minerals. At present the term mineral is used in a restricted sense, for it refers only to those substances which, though not rocks in themselves, are the stuff that rocks are made of. The different minerals of which a rock is composed can sometimes be seen easily by the naked eye. In a piece of coarse granite, for instance, one can clearly distinguish at least three different minerals, namely, (*a*) a colourless, granular, glassy material called quartz, (*b*) a whitish or pinkish material, with rather even surfaces, called feldspar, and (*c*) a dark coloured, glistening, flaky material called mica. When we examine a rock such as sandstone, we often notice that the individual grains of sands (which in many cases may be fragments of quartz) are bound together by quite a different mineral which acts as a cement. The minerals in a rock, however, are not always distinguishable. In many rocks, such as clay or slate, the particles are so minute that they cannot be separated by the naked eye, nor even by a powerful microscope.

The various types of rocks forming the Earth's crust may be divided into 3 main types: igneous, sedimentary and metamorphic.

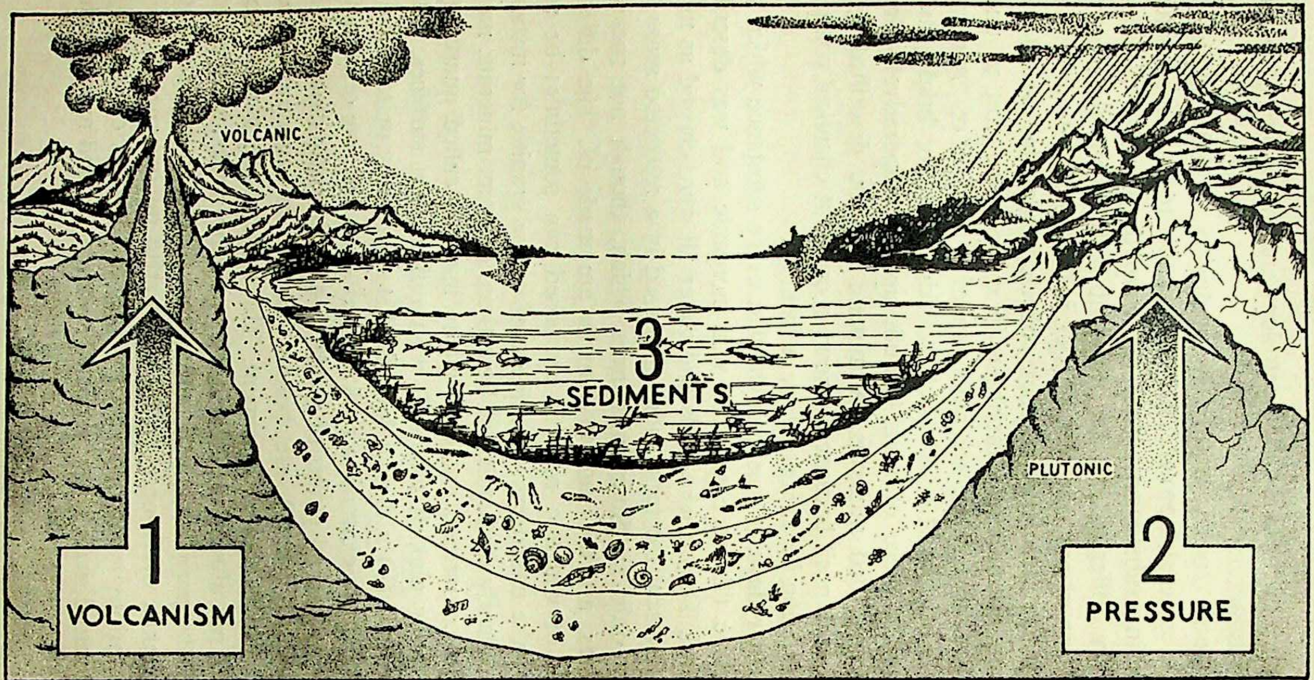


Fig. 12—THE VARIOUS KINDS OF ROCKS

Igneous rocks

Igneous means "fire-made" (igni = fire). Hence, rocks which have been formed by cooling from a molten state are called igneous. The molten material is derived from the hot lower layers of the lithosphere. On solidification this molten material is described as *extrusive* if it was poured out by volcanoes. It is known as *intrusive* if it solidified underground and came to be exposed only when the rocks above it were worn off. Igneous rocks lend themselves to a simple threefold division:

1. Volcanic rocks which were discharged as streams of lava flows from the interior of the Earth and solidified at the Earth's surface;
2. Hypabyssal or dyke rocks which solidified underground but quite near the Earth's surface;
3. Plutonic rocks which solidified underground far below the former land surface.

It can be seen through a microscope that igneous rocks consist of complex mixtures of different minerals which range in size from small particles to well-formed crystals. One of the most common igneous rocks is granite, which forms the core of many mountains. As already noted, even a superficial examination shows that it is a mixture of crystals of quartz, feldspar and mica.

Sedimentary Rocks

The second group of rocks is known as sedimentary rocks. The individual particles in a sedimentary rock are not very compact, and the rock usually consists of several layers, for it is formed by a process of deposition in the following manner: Igneous and other rocks which lie above the sea level are exposed to the action of rain, wind and frost, with the result that they undergo gradual disintegration. The worn-out material is transported to new localities (to the beds of lakes, seas and oceans) where it is deposited in layers. As a result of large scale earth movements, the deposited material may be raised above the sea level, sometimes to several thousands of feet, and become exposed as sedimentary rocks.

Some sedimentary rocks are formed by the consolidation of coarse material. Conglomerate, for example, is formed when gravel is consolidated and cemented together. The consolidation of somewhat finer material, such as sand, leads to the formation of sandstone. The consolidation of still finer material or silt results in the formation of beds of clay and shale. Materials transported in solution form *organic deposits* when they are deposited through the aid or under the influence of animals or plants, but they are described as *chemical deposits* when precipitated without the aid of living organisms. Limestone, gypsum, salt, iron ore, peat, lignite and coal are a few examples of rocks of chemical and organic origin.

Since sedimentary rocks may be old or new, they are often classified according to their age. Thus, there may be Tertiary rocks, Palaeozoic rocks, Pre-Cambrian rocks and so on—their names indicating the geological periods in which they were formed. Sedimentary rocks were formed for the first time some 500 million years ago and ever since the process of their formation has been continual, with the result that they are of very common occurrence on the surface of the Earth.

Sedimentary rocks are sometimes classified according to their origin. Those deposited under the sea are known as marine deposits; those laid down in fresh water by a river are described as fluviatile deposits; and those originating in a lake are called lacustrine deposits. In addition to these, there are aeolian deposits, that is, those deposits which were laid down by winds.

Metamorphic Rocks

Metamorphic rocks (meta = change; morphe = form) are those igneous or sedimentary rocks which have changed their original character by being subjected to great pressure and temperature and other forces in the Earth's interior. A mass of sedimentary rocks may get buried more and more deeply inside the Earth, and come in contact with the zone of great heat in the lower layers of the lithosphere. As a result, it may get baked, hardened and altered—in other words, metamorphosed, changed beyond recognition. Most of the clays which were formed when the Earth was much younger are now turned into hard shales and slaty

rocks. It may be mentioned that rocks which are highly metamorphosed become crystalline, so that it is often very difficult to distinguish them from igneous rocks.

Some Common Rocks

(1) *Igneous*: Table 2 gives some important igneous rocks and their general characteristics:

TABLE 2

COMMON IGNEOUS ROCKS

Colour	*Silicon Dioxide*	*Formed at great depths; coarse grained; large crystals*	*Formed at or near the surface; fine grained; small crystals*
light colour ↑	increases ↑	Granite (quartz, mica, feldspar)	Rhyolite (composition same as granite)
		Diorite (feldspar quartz, ferro-magnesian)	Andesite (composition same as diorite)
↓ dark colour	↓ decreases	Gabbro (ferro-magnesian, some feldspar)	Basalt (composition same as gabbro)

The presence and the size of crystals in an igneous rock depend on the rate of cooling. The large size of the crystals of granite indicate that this rock must have crystallized very slowly at great depths in the Earth, permitting the formation of large crystals. On the contrary, rhyolite which has smaller crystals must have been formed at or near the surface of the Earth. If the cooling is very rapid, crystal formation does not take place, and the product is a glassy substance called obsidian. Both granite and rhyolite are light in colour, but gabbro and basalt have a dark colour.

(2) *Sedimentary*: As already mentioned, weathered material and sediments may be transported from one place to another by water or wind or glacial ice. Those transported by water may be carried in solution or in fragments. When they are being carried

in fragments, the coarser and heavier sediments are dropped first, while the finer or lighter sediments are carried farther. Hence, the usual sequence of deposition, as we proceed outward from the shore of a sea or a lake, is gravel, course sand, fine sand and clay. Table 3 shows the most common sedimentary rocks and the character of the sediments which were involved in the formation of each type:

TABLE 3

COMMON SEDIMENTARY ROCKS

Name of Rock	*Nature of Unconsolidated Sediment*
Conglomerate and breccia	Gravel (pebbles or boulders)
Sandstone	Sand grains (quartz)
Shale	Clay (mud)
Limestone (limestone, marl, chalk)	Limy mud, calcareous sand, shell fragments
Chert, flint	Finely divided silica which may have been deposited from solution
Coal	Plant remains

(3) *Metamorphic*: As we have already seen, both igneous and sedimentary rocks may be altered to form slates, schists or gneisses. Table 4 shows some common igneous and sedimentary rocks and the metamorphic types to which they may change:

TABLE 4

COMMON METAMORPHIC ROCKS

Name of Rock	*Metamorphic Equivalent*
Granite	Granite gneiss
Rhyolite	Rhyolite schist
Andesite	Hornblende schist
Basalt	Slate
Shale	Biotite schist
Limestone	Marble
Sandstone	Quartzite
Bituminous	Anthracite, graphite

Minerals in the Service of Man

Minerals are of very great importance to us and we have many uses for them both as raw material for our industries and as source of energy. In fact, without minerals our entire civilization would collapse like a house of cards.

Coal and oil are the two minerals which are the chief sources of energy for us. Both are associated with sedimentary rocks. Coal is always found interbedded with sandstones and shales, and is never associated with igneous or metamorphic rocks. Oil is usually trapped in beds of sand (through which it can move). These beds lie between beds of shale and clay (through which oil is unable to pass).

Metallic minerals are usually associated with plutonic rocks. There are many metals which play an important part in life and civilization, but by far the most important is iron, which is the main ingredient of all steels. It is a veritable fact that we live in the Iron Age. However, there are scores of other metals which we use. Amongst the light metals we have aluminium and magnesium. Copper is used as a conductivity metal, zinc as a galvanizing metal, lead as a heavy metal, tin as a canning metal, nickel as a versatile metal, chromium as a stainless metal, tungsten as a cutting metal, manganese and vanadium as purifying metals and cobalt and molybdenum as metals that give new properties to steel. Cadmium is used as a metal for resisting the onslaught of weather, titanium is used as a grain-refiner, while beryllium is a new metal with many uses. Gold, platinum and silver are precious metals and so are iridium, palladium and rhodium. Some rare metals are cerium, idium, lanthanum, neodymium, niobium, parseodymium, samarium, tantalium and zirconium. Osmium is the heaviest of all metals. Mercury is the liquid metal and calcium, lithium, potassium and sodium are reactive metals. Certain metals which are only half-metals are antimony, arsenic, bismuth, selenium, silicon and tollurium. Finally it may be mentioned that radium is the life-saving metal used in the treatment of cancer. The above list of metals, it should be realized, is far from complete, and as far as the uses of metals are concerned, we in the twentieth century are only beginning to learn how to use them scientifically and with discrimination.

The Geological Time Scale

The Earth is at least two billion years old and it is impossible not to be curious about the events which have taken place during this long period of time. Fortunately, the history of the Earth has been written for us by Nature itself. It is preserved in a stony volume. The pages of this volume are the geological strata of the rocks of the Earth. Each page, i.e., each set of geological strata, contains the history of about 50,000,000 years. We can unravel this history if we understand the various geological processes of land-building and land-destruction which are continually modifying the surface of the Earth.

There are six basic principles on which the geological history of the Earth is based.

The first principle is that the *seas inundate the land*. Large areas of the existing land masses have often been alternately above and below sea level. This may be due either to the actual elevation or depression of the land in relation to the oceans (isostatic changes) or to the rise and fall of the sea level itself (eustatic changes).

The second principle is the *law of uniformitarianism*. It means that the geological forces that operated to modify the Earth in the past are the same as those that are modifying the Earth at the present time by weathering and erosion and volcanic activity.

The third principle is the *law of superposition*. In weathering and erosion, the substance of the land is worn away and is carried to seas to be deposited in the form of gravel, sand and silt. In the course of time, these become sedimentary rocks. Over a very long period, many layers of sedimentary rocks are deposited one above the other. It is obvious that the youngest rocks are at the top and the oldest are at the bottom.

The fourth principle is the *law of unconformity*. The Earth's crust in some regions has been above and below sea level many times. Suppose that long, long ago a region was under water, so that sedimentary rocks were formed on it. If the region were to be elevated, the upper rocks would be eroded. If the region were resubmerged under water, formation of a new set of sedimentary rocks would take place on the former eroded surface, but they would be unconformable or dissimilar to the previous set of sedi-

mentary rocks. Unconformity, therefore, means that one group of sedimentary rocks is deposited on top of another which has already been folded,[1] and eroded.

The fifth principle is the *law of intrusion*. Sedimentary rocks are often penetrated by igneous material from the interior of the Earth. It is obvious that igneous rocks must always be younger than the sedimentary rocks which they penetrate.

The sixth principle is the *law of organic correlation*. Some sedimentary rocks contain fossils, i.e., the shells and other remains of various animals and plants which were embedded in the rocks, so that they remained buried for ages and were preserved in some permanent form by chemical processes in the rocks. Fossils of different geological ages help the geologist to date the rocks.

The above mentioned six laws may be utilized in reconstructing the past history of the Earth. The time since the rocks were laid down is divided into four eras, each of which is subdivided into several periods, as shown in Table 5.

TABLE 5

Eras	*Systems*	*Periods*	*Approximate Duration in Millions of Years*	*Years Ago in Millions*
CAINOZOIC "Recent Life"	QUARTERNARY	Recent		
		Pliestocene		
		Pliecene		
	TERTIARY	Miocene		
		Oligocene	65	
		Eocene		65
MESOZOIC "Medieval Life"	SECONDARY	Cretaceous	55	120
		Jurassic	30	150
		Triassic	10	190
PALAEOZOIC "Ancient Life"	PRIMARY	Permian	30	220
		Carboniferous	60	280
		Devonian	40	320
		Silurian	30	350
		Ordovician	50	400
		Cambrian	100	500
EOZOIC "Early Life"	PRE-CAMBRIAN	Proterozoic	500?	
		Archaeozoic	1000?	
		Eozoic	?	2000?

[1] See pp. 53-55.

The names of the geological periods are rather difficult to remember. In fact, there is no reason why these names should not be discarded in favour of simpler names. After all, they were given arbitrarily. For example, a geologist who found some ancient rocks in Wales labelled them as "Cambrian" just because Cambria was the old Roman name for Wales. Similarly, Ordovician rocks were named after an extinct Welch tribe. Some one should try to reform these cumbursome names.

Let us recount the history of the Earth through the various geological periods. The Pre-Cambrian era covered nearly half of the entire geological time. Traces of fossils have been found in the later Pre-Cambrian rocks, some in the shape of tracks left by worms creeping through or over the mud, but few are definite enough to show what these earliest recorded creatures looked like. However, they must have been simple-celled.

The Palaeozoic era covered 1/6th of the entire geological time. The systems of rocks deposited in this era are distinguishable from each other by their fossils. They reveal the first appearance of multicellular forms of life. In the Cambrian period there were many algae and especially the reef-building algae. Among animals, trilobites were the most common. Shell-bearing molluscs appeared, and the Cambrian rocks contain the first well-known marine animals. In the succeeding Ordovician period, trilobites and graptolites were abundant, while molluscs spread and corals appeared. Land plants and air-breathing land animals (scorpions) first appeared in the Silurian period but the true graptolites died out. True fishes appeared in the Devonian times and amphibians came into existence later. Spiders and goniatities were also widespread in this period.

The Carboniferous period was a very significant time in the Earth's history. The climate then was probably quite warm and humid, and large areas were inundated by water and turned into swamps. Plants, which in the preceding periods had generally remained hidden beneath water, developed into trees of gigantic size. The vertebrates left the swamps and the three dominant types of dry-land animals, namely, insects, birds and reptiles, appeared in their primitive forms. But after many millions of years the age of ascent became an age of decline. The swamp forests sank down and the sinking layers were compressed by succeeding

layers above them and the primitive forests were slowly carbonized into coal.

During the Permian period there was a considerable extension of land. Earth-folding and mountain-building occurred on a large scale. The southern hemisphere of the Earth was in the grip of a great Ice Age. Trilobites and ancient reef-corals died out and mammal-like reptiles appeared. Many of the Carboniferous plants became extinct.

The Mesozoic era, although it covered only 1/14th of the geological time, is notable for the first appearance of flowering plants and grasses. In the Triassic period, reptiles were the dominant type of animal life. They were not only numerous, but the individuals attained great size. Marine life abounded and vegetation was abundant.

Life of the Jurassic period was somewhat different, though the general types were the same as in the foregoing period. Reptiles were the most distinctive type, and huge dinosaurs, some of which were nearly 100 feet long and 30 feet high, roamed the Earth. Toothed birds appeared.

In the latter part of the Jurassic period chalk (limestone) deposits were formed at the bottom of the sea in many parts of the world. This chalk was made up for the most part of the shells of minute marine animals. The Cretaceous period is notable for the appearance of many modern plants and fishes.

Mammals became the dominant land creatures in the Cainozoic era, which covered 1/30th of the entire geological time. Huge reptiles disappeared, and with the passage of time, the forms of life approached more and more closely to those of the present time. The rise of man took place during the entire glacial period of the Cainozoic era. The Java Man, the Peking Man, the Neanderthal Man and the Cro-Magnon Man represent various stages of the evolution of mankind. The culture of *homo sapien* started with the Cro-Magnon Man about 25,000 years ago. By the end of Pliocene the various forms of life were nearly the same as we find them at present.

The Pleistocene was very remarkable on account of the great climatic changes which occurred at this time. During the million years which geologists allot to this period there were four great glaciations, in which the ice sheets advanced and then retreated

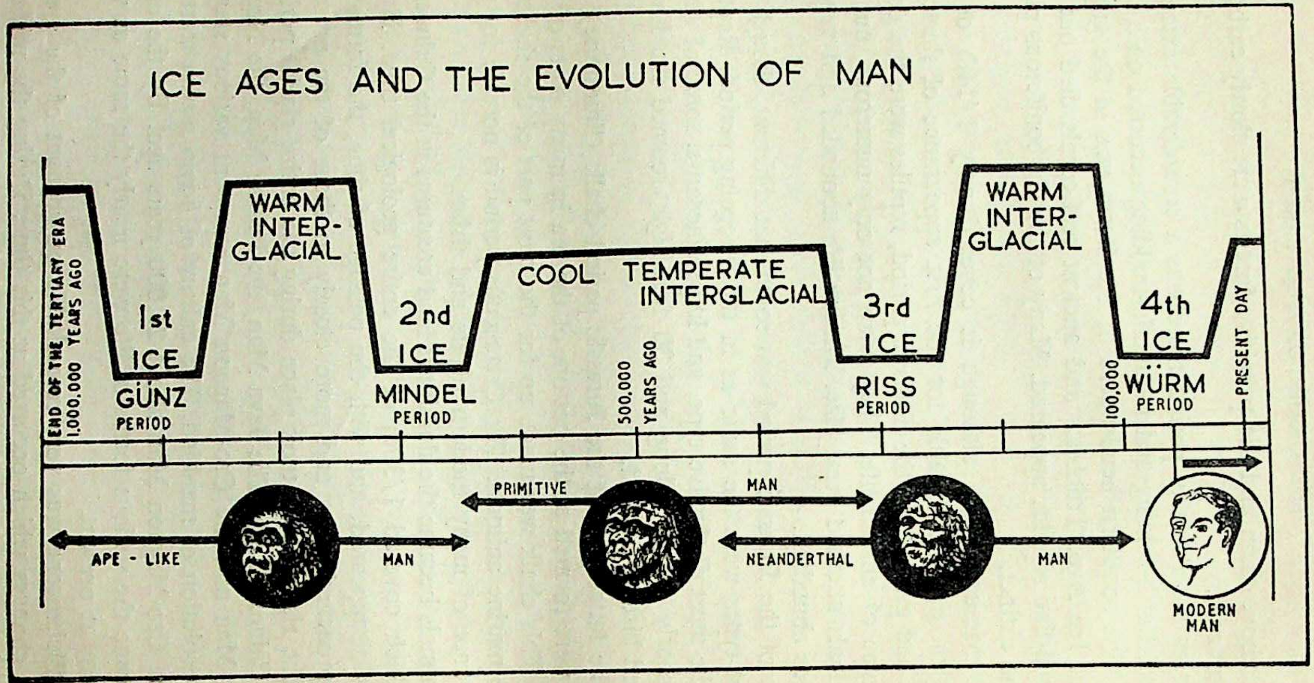


Fig. 13—THE ICE AGES

over the northern part of the world. The last glaciation ended probably 25,000 years ago; the first glaciation occurred probably 40 or 50 times as long. Between the various ice ages occurred periods of warmer climate.

We can see that the Earth has undergone considerable changes to become what it is. Today, much that is useful to us is the gift of the Earth. Fuel for warmth and power; stone, clay and cement for houses; and metals for making machines and tools on which our industries are based—all these are derived from the Earth. We must note in this connection that the various useful commodities are not placed in the Earth at random, and that the occurrence of every mineral deposit has some good geological reason behind it.

CHAPTER FOUR

THE LITHOSPHERE

Introduction

THE Earth's surface is made up of two great divisions, land and water. The former covers only about one-third of the surface of the globe, while the latter covers the rest. As for the distribution of the total land mass, much of it lies in the northern hemisphere of the Earth. The southern hemisphere, on the other hand, is dominated by water.

When compared with the well-known facts of today, the ancient views about the surface configuration of the Earth appear rather queer. The ancients believed, for example, that the Earth's surface largely consisted of land which stretched from east to west. They placed their own country in the centre of this land mass, and arranged land and water symmetrically to balance each other. Thus, the ancient Indians held the view that the Earth's surface consisted of a series of seven concentric belts of land and water with India in the centre. Similarly, the Greeks and the Egyptians considered the Mediterranean with Delphi, and later Jerusalem, to be the centre, with the "Ocean River" round the circumference of the Earth.

Today, we know with precision the actual distribution of the chief land masses (continents) and water bodies (oceans) on the surface of the globe. It is interesting to note that there is not much difference between the highest elevation of land and the greatest depth of water. The highest peak (Mt. Everest) is 29,000 ft., while the deepest abyss (Mindanao) is 35,410 ft. The average height of land, however, is only 2,300 ft., while the average depth of the ocean is 11,500 ft. In other words, if all the land of the globe—continents as well as ocean beds—were to be spread out evenly and reduced to a common level, the entire globe would be covered by an ocean nearly two miles deep. As a matter of fact, we owe the existence of dry land on the globe to the uplifting of the Earth's solid crust into giant folds.

The distribution of land and water over the globe shows an

interesting arrangement, for we find that a continental mass on one side of the globe is always balanced by an ocean on the other side. Thus, Antarctica is opposed to the Arctic Ocean; Europe, Africa and a large part of Asia to the Pacific Ocean; Australia and Eastern Asia to the Atlantic Ocean; and so on.

The Building and Destruction of Land

The main features of the land relief of Earth may be grouped into three major types of landforms: mountains, plateaux and plains. Each of these landforms has evolved from some previous stage, for the most characteristic feature of geological history is steady and ceaseless change. We can be sure that even the highest mountains of the world will, in course of time, be worn down to their roots, since there are a number of forces which are working continually to modify the landforms of the Earth. Some of the forces are endogenetic (internal), that is, they are generated within the Earth itself, while the others are exogenetic (external).

Endogenetic Forces

The fact that even at the top of mountains there may be found limestone and other remains of marine organisms shows that great upheavals have taken place in the Earth's crust, raising ocean beds to heights of thousands of feet. As has already been noted, there are forces acting from within the Earth and working all the time to build up land. One of the most important of these forces is *diastrophism,* which comprises all movements of the outer solid part of the Earth. These movements may be great or small, rapid or slow. Let it be understood that the crust of the Earth is unstable. Its movements may vary from gradual and almost imperceptibly slow to those which are so rapid and violent that they may destroy a very large portion of land or sea bed. Diastrophic movements may be upwards, downwards, or sideways.

Without diastrophism there would be no continents. The structure of rocks, particularly those of sedimentary origin, shows evidence of past crustal movements. Sedimentary beds which were originally laid as parallel strata are found buckled into folds. The upfolds are called *anticlines* and the downfolds are called

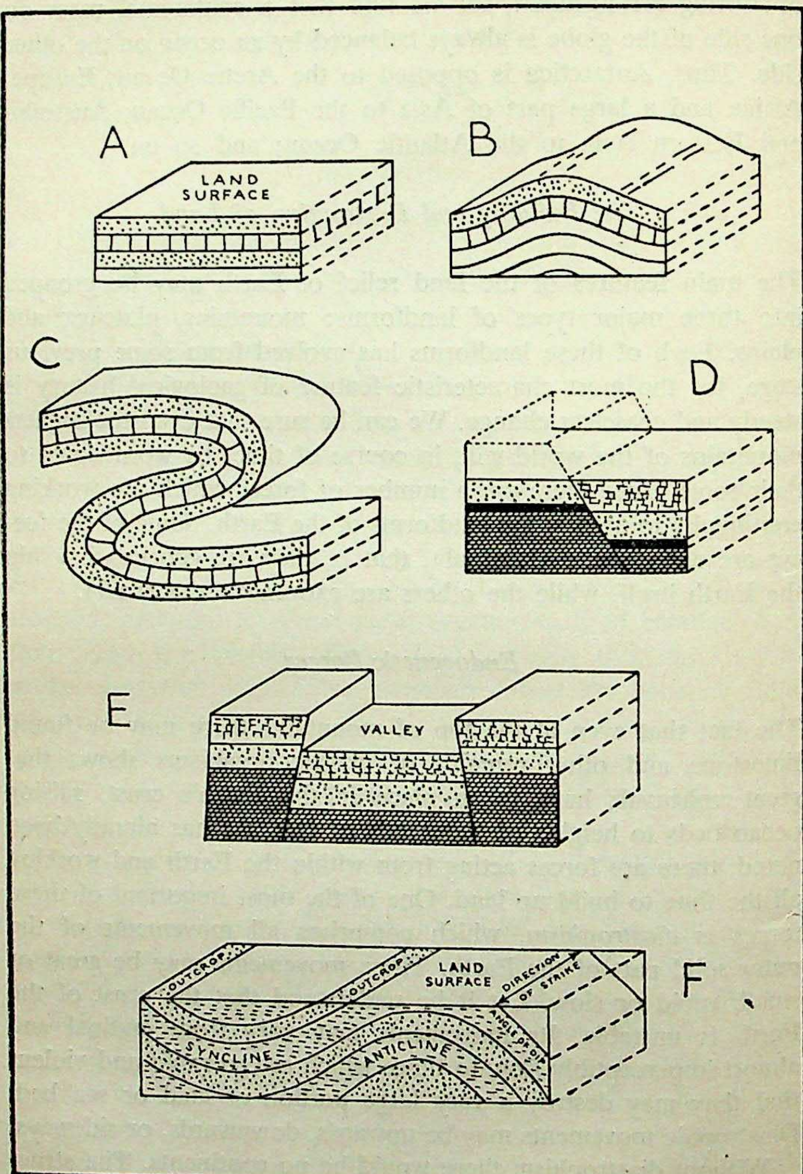


Fig. 14—FOLDING AND FAULTING—(a) Section through strata, (b) A fold, (c) An overfold, (d) A Fault, (e) A rift valley, (f) Some technical terms.

synclines. The arches and troughs of a fold may be only a few feet or they may be of very large dimensions extending for hundreds of miles. The great continental downfolds, or *geosynclines,* become basins of deposition of the eroded material from the adjoining continents. When the material accumulates to the thickness of several thousands of feet, the basin begins to sink with slow down-warping and becomes a region of weakness. Later, as a result of crustal movements the soft material of geosyncline is folded into mountains.

At some places the internal forces of the Earth may cause fracture with or without folding. These fractures or cracks in the crust are called *faults*. On one side of a fault the land slides down along the fault line and causes a break in the rock strata. In mining operations it often happens that a vein of mineral suddenly seems to end but further digging above or below it reveals its continuation. If faulting takes place over an extensive area, resulting in the sliding down of a large crustal mass, a basin or a long depression is formed. Such basins are called *fault basins* and the troughs are called *rift valleys*.

Some of the lines of weakness in the Earth's crust, where both folding and faulting have taken place, seem to have persisted through very long geological periods. It may be that the rigid continental blocks of the Earth's surface do float, as was postulated by Alfred Wegener, on the plastic lower levels, so that they drift towards or away from one another. It is obvious that such a drift of continental masses would give rise to much intensive folding and faulting in the intervening areas.

Another important internal force which operates to modify the surface of the Earth is *vulcanism*. The eruption of a volcano is a terrifying sight. The Earth rumbles, the ground shakes, and bright flashes alternate with pitch darkness. Explosions produce clouds of smoke from the vent of the volcano. The ancient Romans considered that the volcanoes or mountains of fire were the home of Vulcan (the god of fire).

A volcano means an opening or fissure from which gases, molten rock and solid rock fragments are ejected, while the term vulcanism is used to describe all movements of molten rock and all the phenomena that are associated with these movements. Vulcanism is a force which together with diastrophism builds up

land. The molten rock (magma) of a volcano rises along fissures from depths of 30 to 40 miles. By far the greater part of the rocks found in the outer part of the lithosphere are of volcanic origin and are therefore called *igneous*. If the magma fails to reach the surface of the Earth and solidifies underground it forms intrusive rocks. If it flows over the surface and then solidifies it forms extrusive rocks.

The nature of volcanic activity depends on the nature of the material ejected by the volcano. In some cases there may be a quiet flow of molten rock or *lava;* in others there may be explosions giving off large quantities of gases with little or no lava; in still others there may be ejection of gases, lava and solid rock material. Among the vapours escaping from a volcano, steam is the most abundant, while chlorine and sulphur and compounds of these are the commonest fumes. Carbon dioxide is also one of the common gases.

The solid rock material and the liquid lava accumulate about the volcanic opening and build up cones which usually possess a depression at the top. This depression is called a *crater*. When volcanoes cease to be active, their craters are sometimes occupied by water, giving rise to crater lakes. Volcanic cones retain their perfect form only for a short time, because soon after their formation rainfall and other weathering agents begin to wear and tear them.

The eruption of some volcanoes is often preceded and accompanied by earthquakes and by rumbling of the ground. These rumblings and explosive eruptions are due to the force of gases which are held under pressure in the rising magma.

At present there are about 400 active volcanoes in the world. About one-third of these are in continents, the rest are on islands. In general, they are found along the "earthquake zones", which are also the zones of the young folded mountains. One zone is along the Pacific Ocean basin—from the tip of South America to Alaska and thence to Japan and the Philippines. The other zone extends from Central America through the West Indies to the Canary Islands and the Mediterranean; and then from the Mediterranean through Asia Minor and Persia to Indonesia and New Zealand.

Exogenetic Forces: Weathering and Erosion

The atmosphere is responsible for extensive changes, or weathering, on the face of the Earth. Sun, wind and rain gradually wear down the exposed parts of the Earth's crust. These changes are very slow if measured by the span of a human lifetime, but they are very extensive. Even the hardest solid rock and the highest mountains slowly crumble to fragments which eventually find their way to the sea. This continuous alternation of the Earth's crust by the crumbling of rocks and the removal of fragments is called *erosion*. The process of erosion leads to the *denudation* of a piece of land.

The changes brought about by weathering are rather complex, but they may be divided into (a) the physical action of *disintegration* of particles of smaller size, and (b) the chemical action of *decomposition* in which the complex minerals undergo profound changes. Both the actions, mechanical and chemical, occur at the same time, although one may predominate over the other because of local conditions. In dry regions mechanical weathering is more pronounced, while in wet regions chemical changes are more important. Now, let us consider some important agents of weathering.

Agents of Weathering

THE SUN. When a piece of rock is exposed to the rays of the Sun, its surface becomes hot and tends to expand, while the interior of the rock mass remains cool and unaffected. In this process the surface layers of the rock are pulled away from the inner part and detached from the mass. This shelling off process is called *exfoliation* or *onion weathering*, and is most widespread in hot regions, especially desert lands where there is little covering of vegetation to protect the rocks.

THE FROST. When water freezes it expands by about 1/10th of its volume. Hence, when rain water freezes in a crack of a rock it expands and widens the crack, so that in course of time great masses of rocks are broken up from the mountain sides. This phenomenon is known as *frost shatter*. The action of frost is especially important in high mountains, but it is quite widespread

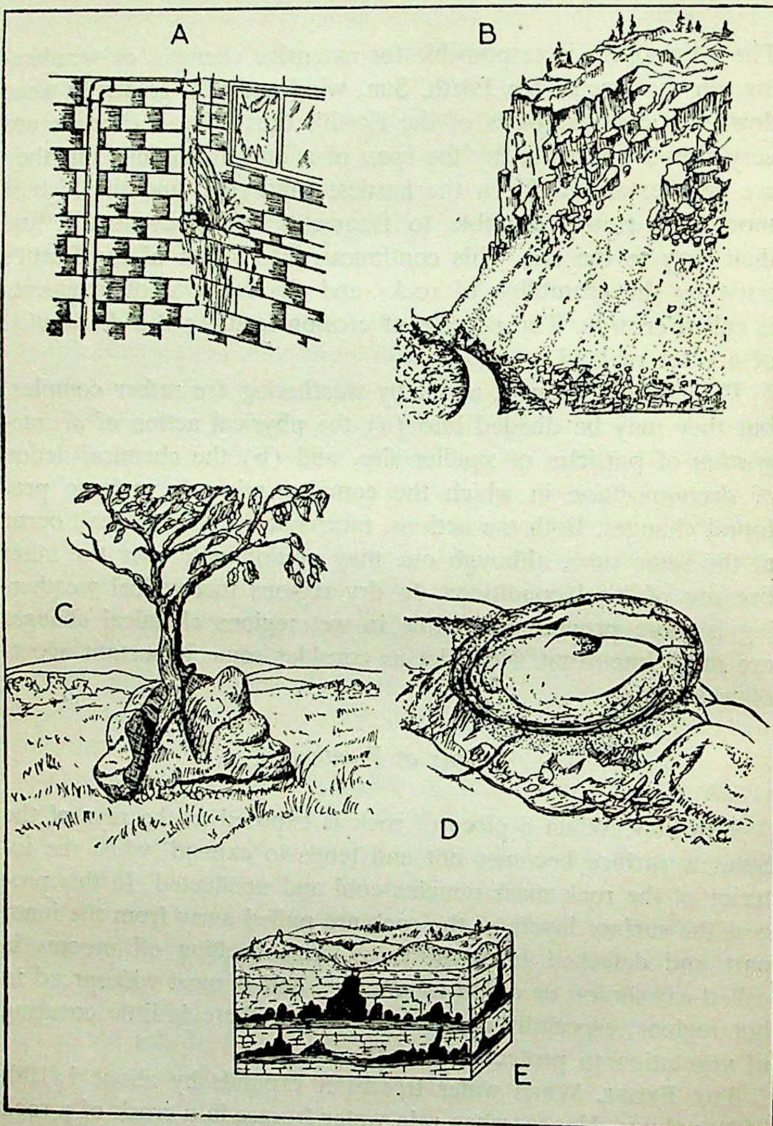


Fig. 15—WEATHERING—(a) The iron pipe is broken by the expansion of freezing water, (b) Talus at the foot of a cliff is formed by the action of frost, (c) The rock is split by the growth of the root of the tree, (d) A boulder is exfoliated, (e) Caverns are formed in limestone.

over a large part of the Earth.

THE WIND. The wind removes loose dust and sand from hill slopes and other land surfaces and exposes the rocks to the action of other weathering agents. The action of the wind becomes more pronounced when it is armed with sharp particles which cut and polish the surfaces of hard rocks, especially in a desert region.

The wind in a desert region blows the sand nearer the surface and so undercuts rock surfaces in neighbouring cliffs. Such undercutting may lead to the toppling down of blocks of rocks from the higher levels. The action of the wind is important not only in regions which are true deserts, but also in dry countries where the soil, when exposed by cultivation, is blown away.

THE RAIN. The water which falls as rain on the rocks performs mechanical as well as chemical action. The former results in the washing away of loose particles or soft rocks, so that what is left behind is either a bare rock surface or coarse deposits forming a sandy or stony desert.

As for chemical action, not only is water itself able to dissolve some of the minerals, but the rain water, containing a fair amount of carbon dioxide, works as a mild acid and dissolves certain minerals, especially calcium carbonate or limestone. The chemical action of water is particularly important just below the land surface. In a limestone area the rain water sinks underground, dissolving some of the limestone and eventually forming underground channels and caves.

THE RUNNING WATER. Some of the rain water collects to form tiny streams, which join to form rivers. River water does have a chemical effect on rocks, but its most important action is mechanical. The moving water itself erodes the banks and bed of a river, while the stones, pebbles and sand which a river carries with it also work as powerful erosive agents.

Running water is, in fact, the most important agent operating to modify the shape of the Earth. The processes of erosion and deposition produce far reaching changes. The rills, rivulets and streams on a hillside carve intricate systems of little depressions which extend upwards, eating up higher and higher into the sides of the hills. The small depressions at the side of the hills are called gullies, and the larger depressions at the base of the hills

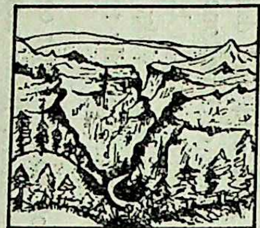
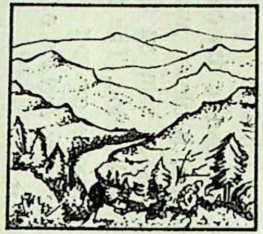
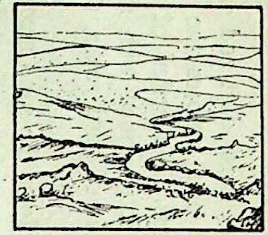
	YOUTH	MATURITY	OLD AGE
Stream Profile			
Course of stream	Rather straight	Meandering	Very meandering
Width of stream	Narrow	Medium	Broad
Topography	Scenic; falls and rapids. Flat upland with V-valleys	Rounded; falls and rapids uncommon	Flat; no falls and rapids
Drainage	Poor; swamps and lakes in uplands	Very good; no swamps or lakes	Poor on flood plain
Vegetation	Variable	Completely covered	Swampy
Flood plain	Almost none	Medium	Wide. Levees and oxbow lakes
Tributaries	Few	Very many	Few

Fig. 16—THE CYCLE OF RIVER EROSION

are called ravines. Ravines lead to the main channel which runs through the valley. A system of gullies, ravines and valleys resembles the trunk of a tree with many branches and twigs. The whole drainage system is engaged in erosion. Slowly but surely the ridges and hills are lowered, and the final result is a featureless level surface called a *peneplain*. In time, a peneplain may be uplifted again, causing the cycle of erosion to begin anew. The cycle of erosion which involves the transformation of an uplifted area into a peneplain may be divided into three stages, and the topography of each stage has its characteristic features.

In the early stage, or youth, the topography is dominated by uplands. The river flows through V-shaped valleys with steep walls. The tributaries are few and the divides between adjacent valleys are broad. The chief work of the river is downcutting, and its course is marked by swift rapids and falls. As erosion proceeds, the tributaries become well defined, ravines multiply and the broad divides change into narrow ridges, so that the region passes to the second stage, viz., Maturity.

In the mature stage, a region possesses a rugged topography. The valleys are numerous and tributaries are well developed. The divides are smoothened. The gradient or slope of the river decreases, and so does the downcutting action. The erosion of the stream is directed at the banks and the valley is widened.

In the third stage, namely, old age, little erosional work remains to be done, and the region is characterized by broad valleys with gentle slopes and low divides. The low relief and small gradient make the rivers sluggish. Deposition becomes the dominant activity. Finally, the region becomes a peneplain.

The cycle of erosion described above may be interrupted at any stage by geological forces or by the deposition of glacial debris and flow of lava.

THE MOVING ICE. A glacier, which is a river of ice, naturally slides down the slope of the hill but it moves very slowly, just a few inches every day. However, even by its sheer weight, a glacier scrapes and polishes the ravines of high mountains into wide smooth-walled valleys. In addition to its load of ice, a glacier carries a good deal of rock fragments some of which are embedded in the ice mass. These rock fragments serve as scraping tools and help the glacier in scooping out its valley. The rock frag-

Fig. 16—THE CYCLE OF RIVER EROSION

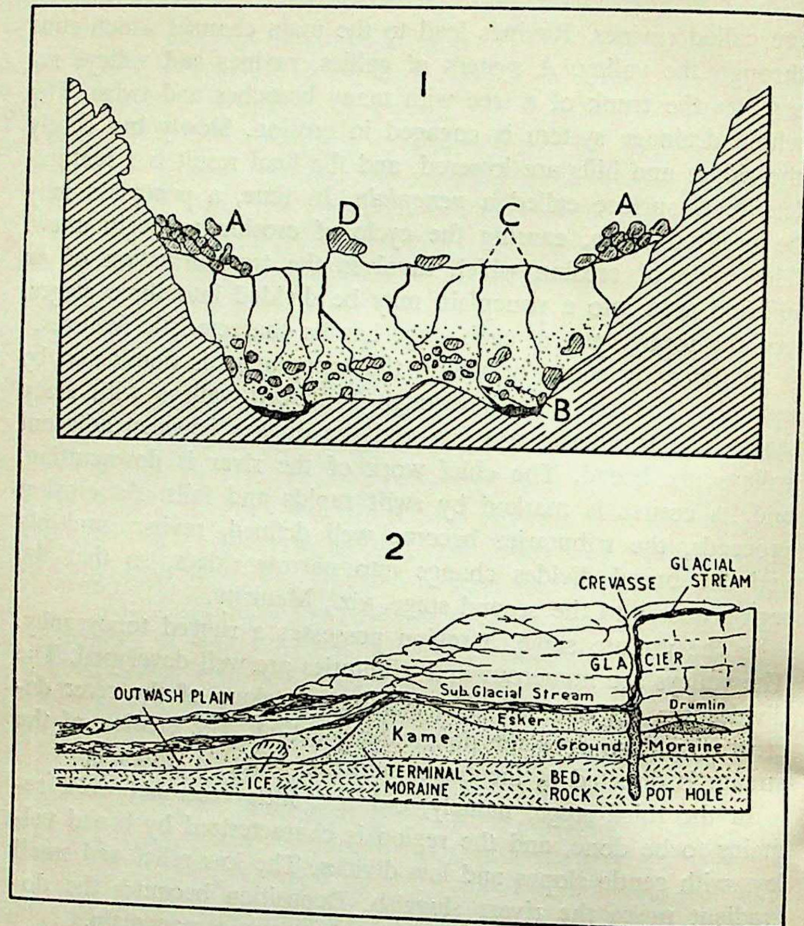


Fig. 17—GLACIAL FEATURES—1. Cross section of a glacier: (a) Lateral Moraine, (b) Ground moraine, (c) Crevasses, (d) Ice table. 2. Cross section of a glacier at its front.

ments are blunted and transformed into boulders. The boulders deposited by a glacier show scratches, called *striae*.

Prolonged glacial action changes a V-shaped valley into a U-shaped one. A tributary valley which after the disappearance of ice may be left hanging above the floor of the main valley, is known as a *hanging valley*. The plucking and erosive actions of glacial ice often produce in the upper reaches of a glaciated valley amphitheatre-like shapes, called *cirques*. In high latitudes, glaciated valleys may be partially drowned by the sea to form depressions called *fiords*.

When glaciers melt, they deposit masses of rock debris called *glacial drift*. The material deposited by glaciers at their sides or at their ends, is known as *moraines*.

Mountains and Plains

As was said earlier, the mountains of the world are being gradually worn down, and their material, before it is finally transported to the sea, is deposited in valleys and plains. Thus the loss of the mountain is the gain of the plain, and the death of the mountain is the birth of the plain. "One teaspoon of mountain rock dissolved in a quart of rain—that is the formula the mother mountain feeds her geological child, the plain, with." Let us consider certain features of mountains and plains.

MOUNTAINS

Mountains are landforms of high relief, and they have more sloping land than flat land. A study of a topographic map of the world will show that mountains are not scattered haphazard over the globe. Most of the great mountain systems run parallel to the margins of the oceans and continents, but a few smaller chains are found scattered over the land. Generally speaking, the former are the result of great crustal movements, while the latter are produced by erosion or volcanic activity.

(*a*) MOUNTAINS PRODUCED BY EROSION. Mountains may be produced by differential erosion of rocks, when the softer material is eroded leaving the more resistant rocks as high ridges between stream divides.

(*b*) Mountains Produced by Volcanic Activity. Volcanic mountains may be formed singly or in groups, in the form of cones and high plateaux. They are built up by the piling of lava and other volcanic material.

(*c*) Mountains Produced by Crustal Movement. Most of the great chains of mountains have been produced by gigantic crustal movements. The presence of rocks of sedimentary origin and of marine shells and fossils even at the top of many mountains shows that these areas must have been uplifted from the flat bottoms of shallow seas and pushed upward in folds. In addition to the fold mountains, which consist of large synclines and anticlines, there are mountains which are supposed to be the result of faulting on a large scale.

As has been already remarked, most of the great mountain systems of the world are found on the margins of the continents. Some of the huge folds in these mountains contain sedimentary rocks which are several thousand feet in thickness. This not only indicates that these sedimentary rocks were formed in great geosynclines but also that their deposition must have been accomplished during a very long period.

Here, we can only briefly discuss the origin of these mountain systems. Let us picture a relatively high continent which was being gradually eroded and its material transported to a bordering geosyncline. Under the gigantic load of sediments the geosyncline sank. The removal of material from one section to another disturbed the equilibrium of the Earth's crust, and during periods of crustal movements the sedimentary beds were pushed from either side and compressed and thrown into gigantic and complex folds.

A number of theories have been advanced to explain the crustal movements involved in mountain building. All these theories, however, are speculative and all that we can say is that the forces involved in these crustal movements must have been tremendous.

We live in a period of the Earth's history which is rather quiet, but there have been periods in the past when the Earth saw great upheavals, leading to the birth of great mountain systems. Geologists tell us that there were four great mountain-building movements in the Earth's history. The first was the Charnian Earth-movement in the Pre-Cambrian era; the second was the

Caledonian Earth-movement which occurred largely in the Silurian period more than 300 million years ago; the third was the Aromorican Earth-movement which took place in the late Carboniferous times; the last, namely, the Alpine Earth-movement, to which we owe the development of most of the lofty mountain system of the present day which took place in the Tertiary times some 40 to 50 million years ago.

The Influence of Mountains on Human Life. Mountains exercise a far-reaching influence on human life. They profoundly modify the climate of a place and serve as the source of rivers. But here we may leave out these aspects of their importance and discuss only some of their direct effects on human life.

Mountainous regions are cold and are covered permanently with snow above 9,000 feet. They are generally thinly populated and the people usually occupy the valleys which may be cut off from each other because of uneven terrains. Communication and movement are therefore generally difficult in the mountainous areas, and people live in isolated groups. As a result of isolation they tend to become conservative and remain backward but they are sturdy, brave and jealously watchful of their freedom. The small patches of soil are usually unproductive and land has to be carefully terraced for cultivation. Owing to lack of agricultural and other resources the struggle for existence is rather hard and this fosters in the people such qualities as frugality, providence and industry. Social groups are divided into tribes which have very little mutual co-operation amongst themselves. Tribes are further divided into clans. Each tribe and clan tries to preserve its established customs and practices, and there is great unwillingness to accept new ideas.

In modern times, the development of means of communication has resulted in the breaking up of the isolation of many mountainous areas, and their contact with the outside world has been fast increasing. It may be noted that although agriculturally poor, the mountains are not without resources. They usually contain mineral and forest wealth, grazing lands, and a great potential for the development of water power. They also offer scenic beauty and attractive summer resorts and recreation spots.

PLAINS

Plains are low-lying areas with a more or less level surface. They may be divided into two types—coastal plains and inland plains. Coastal plains may be formed by the deposition of silt by rivers, but sometimes they may be the result of subsidence of a block of coastal land or the uplifting of land from under the shallow sea. Inland plains may be either small in extent or may extend far into the interior. Sometimes they are cut off from the sea by high land.

Communication and transport are comparatively much easier in the plains than in mountainous areas. This accounts for the fact that the plain regions contain most of the population of the world, and have always been the chief centres of human civilization and progress. Life is relatively easy in plains and the people have a greater choice of occupations. The soil is usually fertile so that agriculture is the dominant activity. The level nature of the country facilitates intercourse and leads to exchange of ideas and to the development of trade and commerce. The people realize the need for co-operation and large-scale organization, so that a tribal structure of society cannot survive for long. An easy life tends to foster a desire for pleasure and peace.

Life on a coastal plain is not very different from that on an inland plain. The indentation of a coastline facilitates the development of ports, which encourage seaborne trade with other countries. As a result of greater contact with foreign countries, the people possess a relatively progressive and cosmopolitan outlook.

CHAPTER FIVE

THE HYDROSPHERE

Introduction

DAY after day on a long ocean voyage, you will not see much around yourself except the blue dome of the sky over the deep blue ocean. In such surroundings you may begin to feel that our world is a world made up of water. To a large extent this is true, because the hydrosphere, or the sphere of water, does cover the major portion of the Earth's surface. Of the total area of the Earth's surface which is about 196 million square miles, no less than 141 million square miles (roughly 71%) are covered with water, the total volume of this water being about 324 million cubic miles.

Man lives on the land surface of the globe and exploits it for his needs, but he cannot control or plunder the oceans in the same way or to the same extent as he controls or plunders the land. He has a fair knowledge of the land areas but he has yet to learn a good deal about the oceanic world; its submarine canyons, its towering mountains and deep trenches, its continental shelves and continental slopes, its countless animals and plants, its waves and current patterns, and its food potentialities. Oceanography as a science is hardly a hundred years old.

The mighty oceans, majestic and awe-inspiring, lie all around us. They fill five huge basins, of which the Pacific with an area of more than 60 million square miles is the largest. The Atlantic covers 30 million square miles, and the Indian Ocean 28 million square miles. The Arctic and the Antarctic Oceans are much smaller, but their extent is rather uncertain, for large areas of them are frozen.

Our huge continents are no more than small projections of land above the surface of the oceans, and it is their inevitable fate that they should be worn down bit by bit. Particle after particle of this eroded material is destined to pass on to the oceans. Indeed, it is the oceans of the world which are permanent and lasting, and at any given time it is their influence which is all-

pervading. The winds which blow on the Earth are caused by the oceans and go back to them. The rains which rise from the oceans return to them by means of rivers. It was in the oceans that life began billions of years ago and it is to the ocean that all things living and non-living must eventually return. Verily, the ocean is the beginning and the end of life.

The Permanency of Ocean Basins

Geologists differ in their opinions regarding the origin and history of the great depressions occupied by the oceans. Broadly speaking, there are two schools. According to one school, the continents have moved into their present positions by the drifting apart of portions of what was once a huge continent. The other school holds the view that the Earth's surface has undergone great changes by the sinking of whole continents, or large parts of the continents, under the waters of deep oceans. However, both the schools agree that certain broad topographical features of the oceans and continents have existed since an early time in the Earth's history, and whatever be the mode of origin of the ocean basins, it is certain that they are very, very old. As a proof of this antiquity, it may be noted that nowhere on the present land masses do we find any rocks which resemble in their composition the organic ooze (or liquid mud) at the bottom of the oceans. This obviously means that no part of the ocean floor has been raised above the ocean surface since the organic oozes began to accumulate upon it. Thus, the ocean basins have been permanent for a very long time, covering almost the whole period during which life has been evolving upon the Earth.

Yet the boundary between sea and land must be regarded as transitory and temporary. In the past the sea has arisen several times only to fall again.

To cite one of many examples, fifty million years ago the lofty Himalayas were under the waters of a huge warm sea. Limestone which is found in many places on the continents, even on the mountaintops, is an indication of the presence of sea in the bygone ages. We are sure of this because limestone is made of shells of countless minute sea creatures who died and whose remains sank and settled on the bottom of the oceans. After a period of time

too long to be measured, their remains solidified and consolidated into rocks. After the passage of many millions of years these rocks were uplifted by the buckling and folding of the Earth's crust, and in many places came to form the backbones and coverings of the hills and mountains. Like limestone, all shales as well as sandstones had their origin in the seas. The rocks of which the Sphinx and pyramids of Egypt are made were formed in the sea. Similarly, the rocks of which the Taj Mahal is built originated in the sea in the Palaeozoic times.

Again and again the ocean has come out of its deep basin to flood the land. The large-scale displacement of ocean water may be due to one or more of the following causes:

Firstly, the slow process of the warping of the Earth's surface over a long period may result in the submergence of large areas of land under the sea. Secondly, the disintegration of land and the deposition of this material in the ocean basins displace a corresponding amount of water to flood the land. Thirdly, volcanoes sometimes erupt on the ocean floors, and the lava which they pour out displaces an equal volume of water. Fourthly, during the last million years glaciers and icecaps have played a dominating role in changing the sea level. In the period known as the Great Ice Age, glaciers and ice caps of great depth covered extensive areas of the world four times, and they melted and withdrew the same number of times. Each thickening of the ice sheets meant that water was drawn from the oceans and the sea level was lowered, and each melting of the ice sheets meant the return of enormous quantities of water to the oceans and the consequent raising of the sea-level.

We live in the fourth period of the melting of ice, and the stage has been reached when only half of the ice formed in the last glaciation remains locked up in the ice caps of Greenland and Antarctica and in the glaciers on the mountains. The melting ice has raised and is raising the level of the seas.

The Sea Bed

The depths of the seas and the oceans are measured by a depth-finder. Sound waves are directed from the bottom of a ship downwards to echo back from the ocean floor. Since we know the

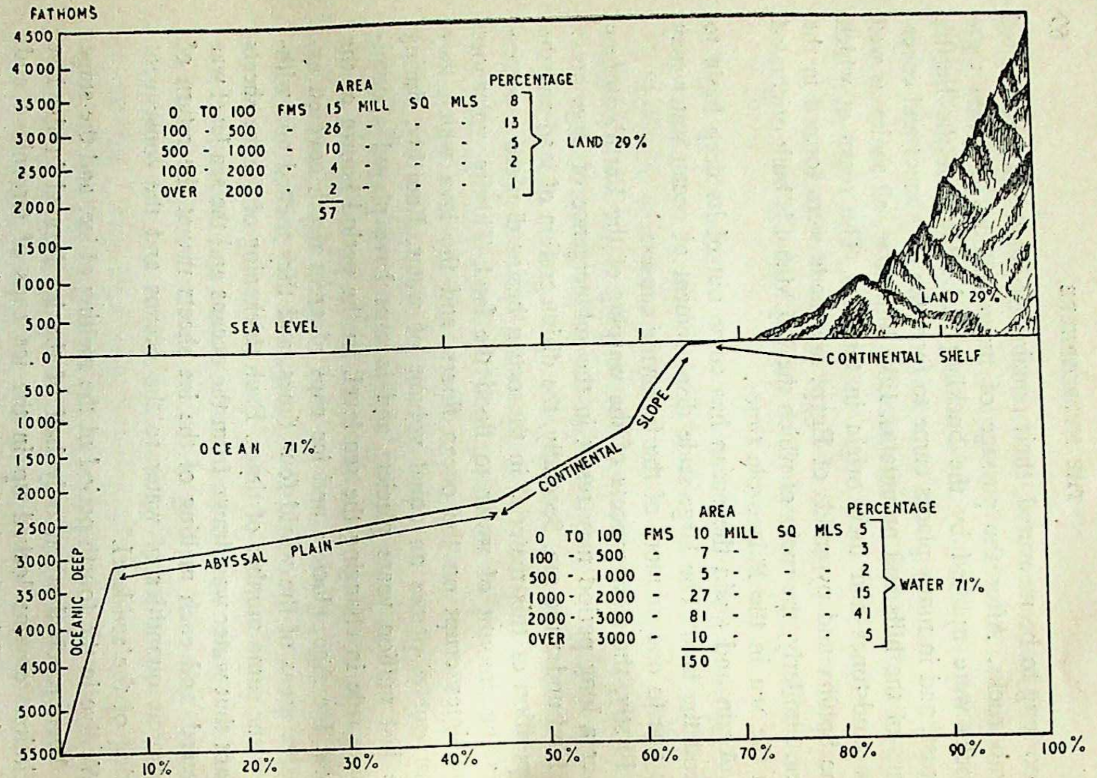


Fig. 18—THE OCEAN BED

velocity at which sound travels, we can calculate the distance between the ship and the ocean floor. In this way, data have been collected which give us a detailed knowledge of the general topography of the oceans.

Topographically, the oceans can be divided into three regions: the continental shelves, the continental slopes and the floors of the deep sea. Around the continents below the sea level a small part of the sea floor forms a shallow platform of varying extent where the depth is less than 100 fathoms (600 ft.). This is the *continental shelf*. It may be broad or narrow or even wholly absent. As a rule, it slopes very gently, dropping about 1 foot for every 500 feet. It is upon this gentle slope that all the heavier material brought down by the rivers is deposited. Beyond the continental shelf and up to a depth of 2,000 fathoms is the *continental slope* which has an inclination of 1 in 10 and upon which the finer materials from the land finally come to rest. The continental slope varies in extent. However, at about the 2,000 fathom line the continental slope gives place to a vast undulating plain—the *abyssal plain*. This plain lies beyond the reach of the material washed down from the continents. It is covered by oozes made up of innumerable decomposed skeletons of animals and plants.

Less than 2 per cent of the ocean floor lies at depths greater than 3,000 fathoms. Ocean *deeps* are long trenches which are often close to the continents. The deepest trench, the Mindanao Deep, is east of the Philippines and is 6½ miles deep. The Tuscarora Deep near Japan has about the same depth.

The ocean floor is broken not only by deeps but also by long ranges of mountains under the waters of the oceans. The longest ridge, known as the Atlantic Ridge, stretches for 10,000 miles from north to south in the mid-Atlantic.

We know very little about the deep seas which occupy nearly half of the Earth's surface. These depths are a challenge to men, for owing to the tremendous pressure of water the human body cannot go below a certain depth, and even in a diving suit a person cannot descend in the sea to a depth of more than 500 feet. In fact, very few people have ever been to depths which do not receive sunlight. In 1949, William Beebe established a record when he went down to a depth of 4300 feet in a steel sphere known as

benthoscope. However, depths of nearly two miles have been reached in a free-moving vessel which does not have to be suspended from a cable.

Below the sea surface, light fades very rapidly. Below the depth of 200 or 300 feet the red rays which bring the warmth of the Sun do not penetrate. At 600 or 700 feet the green rays are absent. At 1,000 feet only the brilliant blue rays are present. The greatest depth is reached by the utra-violet rays which penetrate to 2,000 feet. Below this there is only the perpetual darkness of the deep sea.

This dark world must be a terrible place. There is no plant life below the sunny upper layers of water which is no more than 600 feet deep. But even below this depth there is teeming animal life. Here the creatures prey upon each other and there is a furious competition for food. Some of them have sabre-toothed jaws and large mouths. Others have elastic bodies and can devour a fish several times their own size. Some have torches which they can switch off or on; others have rows of light over their bodies; still others can eject a fluid which makes the surrounding water luminous. These lighting devices help these animals to find and catch their prey. Let it be repeated, however, that we know very little about the animal life and other mysteries of the deep oceans.

Salinity

Water is such a great solvent that almost all substances dissolve in it to some extent. From its very beginnings the crust of the Earth has been subjected to the slow but persistent dissolving action of water. The rain falling on the land carries dissolved minerals into lakes and rivers. The rivers and the seas washing the coasts of the continents have also been dissolving the salts and minerals and carrying them to the oceans. Sea water therefore contains, in a very dilute solution, all the elements which compose the minerals and salts of the Earth's crust. The most important salt in this solution is the common salt (sodium chloride). It has been calculated that there are enough salts in the sea to cover the entire globe, when dried, with a layer 150 feet thick, or to cover the present land area with a layer nearly 500 feet thick.

The sea water must have been changing steadily in composition throughout the Earth's history, yet it is a fact that the amount of dissolved salts which the rivers contribute to the sea every year is very small, i.e., 1/2,000,000th of the total salt in the ocean. Even this small fraction is not all given to the ocean, for some of it is thrown out by precipitation or withdrawn by animals or plants or thrown on the land by wind-blown spray or evaporated to the atmosphere. We must assume then that if rivers have added to the salinity of the oceans in the past, their contribution has been very small. The present sea water is probably not very different chemically from the water which first collected on the young barren Earth. A large part of the salts in that water were derived from the rocks of the hot crust at a time when conditions of temperature and sometimes of pressure were more favourable for solution than they are now. Furthermore, since the composition of the ocean salts is notably similar to that of volcanic gases, it seems probable that the chief source of the salt in the seas are the rocks in the lower layers of the Earth.

The uniformity in the proportions of the salts in sea water is brought about by the thorough mixing of the waters of the oceans. This mixing is done by currents and tides and waves, which move great bodies of water from one place to another. Further mixing takes place as water wells up from below to take the place of water removed from any surface. In spite of this mixing, variations in salinity do occur from one part of the ocean to another. In some areas the solution may become more concentrated by evaporation and, in others, more dilute by the addition of water from rivers, rain, snow or the melting of ice bodies. For any or all of these reasons certain seas are more salty than others. The North Atlantic has a salinity of 35 parts per thousand, the Red Sea has 40 parts per thousand, while the Baltic has only about 7 parts per thousand.

The determination of salinity is an extremely important part of the routine in oceanographical work, because salinity is directly related to the density and temperature of water, and small differences in salinity, and thus in density and temperature, give the clue to the flow of surface currents as well as the movement of masses of water at various depths.

Movements of the Seawater

The water of the seas and oceans does not remain still. It moves in various ways and these movements are generally caused by waves, tides or currents.

Waves

Waves are the most familiar and at times the most spectacular of all the movements of the hydrosphere. Waves higher than 25 feet from crest to trough are rare, but storm waves may be twice this height. They are caused by the passage of the winds and make a confused pattern in the open sea—overtaking, passing or sometimes engulfing one another. A wave is an oscillation of the water particles at the surface but the water in a wave does not advance with it. Thus a cork floating on the waves moves up and down but unless it is pushed along by the wind itself, it changes its position only very slowly. Each water particle in a wave describes a circular orbit but returns to almost its original position.

Once a wave is formed, it grows by the pressure of the wind against its windward slope. When the height of a wave reaches one-seventh of its length from trough to trough, the crest becomes a ridge and curls over, with the result that the wave breaks. Hence, the longer a wave the higher it grows before breaking. When a wave runs into shallow water its base is shortened by friction and it breaks, so that the on-rush of water on the coast is called a *breaker*. When the winds drop or when the waves run out of a storm area they become rounder and more regular. In other words, they change from waves to swells. Swells with a length of a thousand feet and a height of 30 or 40 feet are common, while the longest swell actually recorded was 3700 feet high. Swells may travel for thousands of miles and yet remain sufficiently strong to cause great damage to the coasts which they strike.

When a wave collides with a tidal current coming from the opposite direction, the fury caused is like that seen in the encounter of two wild beasts. The dreadful "roosts" of Scotland are the result of such collisions. A vessel caught in the roosts becomes entirely unmanageable and often founders.

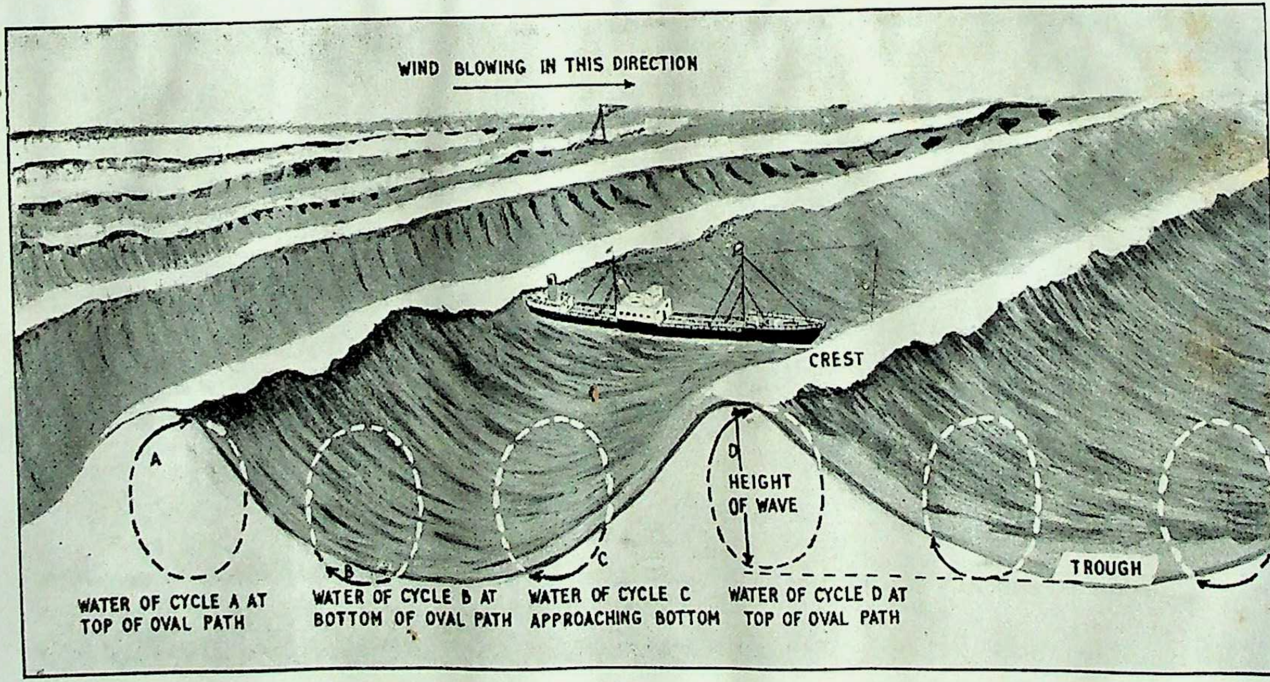


Fig. 19—WAVE MOTION—Though the waves themselves travel forward, the water of any one wave really moves in an orbit.

The force of a furious wave may be as much as 6,000 lb. per square foot. The most powerful waves usually belong to the class of storm waves or seismic waves. The latter are produced by under-sea earthquakes, and the first warning given of them is that the sea withdraws and the voice of the breakers is hushed.

Tides

The second kind of movement of the hydrosphere is called tides, and is caused by the gravitational attraction exerted by other heavenly bodies, especially by the Sun and the Moon. The Moon, since it is so much nearer to the Earth, exerts about twice the pull of the Sun. When the Sun and the Moon are in such a position as to pull at the same time and in the same direction, the tides are very high and are called *spring tides;* when pulls of the Sun and the Moon counteract each other, the tides are weak and are called *neap tides.*

There are a number of factors which make the time-table of the tides very complex. Firstly, the Sun, the Moon and the Earth are rarely in a straight line and their location in relation to each other varies a great deal. Secondly, the distances of the Sun and the Moon from the Earth are not constant. Thirdly, the Sun and the Moon are not always on the same side of the Equator. Fourthly, our globe is not entirely covered with water. Fifthly, the configuration of the coast helps or hinders the tides. In spite of these complexities, however, the tides follow each other with very great punctuality at any given coast.

As a rule, the time-table of the tides is geared to the movements of the Moon. Each day the high tides arrive about 51 minutes later than on the previous day, the period of 51 minutes being the daily lag or falling behind in the rising and setting of the Moon. Between the two high tides, which are separated by an interval of 24 hours 51 minutes, there is another high tide and two low tides. Hence, the timing of the tides at a coast may be as follows:

High Tide	6.00 P.M.
Low Tide	12.13 A.M.
High Tide	6.25 A.M.

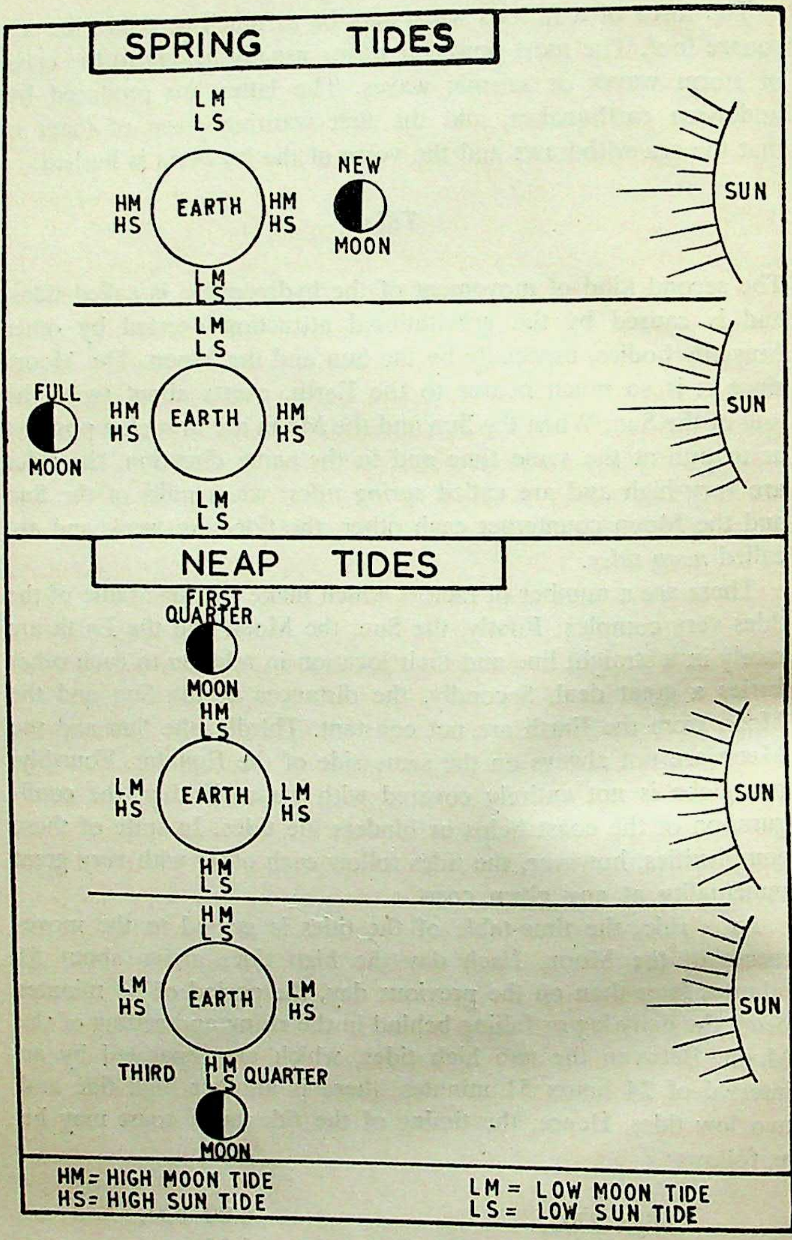

SPRING TIDES
LM
LS
NEW
MOON
HM
HS
EARTH
HM
HS
SUN
LM
LS
LM
LS
FULL
MOON
HM
HS
EARTH
HM
HS
SUN
LM
LS
NEAP TIDES
FIRST QUARTER
MOON
HM
LS
LM
HS
EARTH
LM
HS
SUN
HM
LS
HM
LS
LM
HS
EARTH
LM
HS
SUN
THIRD
HM
LS
QUARTER
MOON
HM= HIGH MOON TIDE
HS= HIGH SUN TIDE
LM = LOW MOON TIDE
LS = LOW SUN TIDE

Fig. 20.—TIDES

Low Tide	12.38 P.M.
High Tide	6.51 P.M.

You might like to know the reason for the occurrence of a high tide between two high tides which are separated by an interval of 24 hours and 51 minutes. For this you must understand the way in which ocean tides are caused by the Moon.

The Moon attracts the side of the Earth facing it more strongly than it does the centre of the Earth. The Earth is a rigid body, though not rigid enough to prevent very slight movement of its crust in response to this pull. The envelope of the hydrosphere, on the other hand, is not rigid but mobile, so that every particle in it responds to the attraction, and water is heaped up in the direction of the Moon's pull. On the side of the Earth away from the Moon the surface of the globe is attracted less than the centre and the hydrosphere less than either, so that the water becomes heaped up there also. The phenomenon is similar to the stretching of a rubber balloon, which when inflated swells at both ends. Thus, as the Moon-attracted water rises on one side of the Earth, a corresponding tide is pulled up on the other. That is why the tides follow each other in periods of half-days.

The extent of the rise and fall of the tide varies considerably in different places. In mid-ocean the difference between the high and the low tides is not very noticeable, while on the oceanic islands it is two or three feet. On the shores of the continents, especially in narrow bays and inlets, the height of the tide is much greater. The largest tidal range in the world occurs near the Canadian coast, at the head of the Bay of Fundy, where the difference between the high and the low tide is about 50 feet. When high tide enters an estuary, which is wide at the coast but rapidly narrows down, the waters are pressed together and piled up into a several feet high foaming wall which rushes on with a great noise. Such a wall is known as a *bore* or *eagre* and is a great danger to shipping.

A good knowledge of tides is very important to the navigators, because at many ports the arrival and departure of vessels is governed by the time-table of tides. Moreover, on a dangerous shoal a difference of one or two feet in the depth of water may determine the safety of a ship. That is why it is one of the tasks

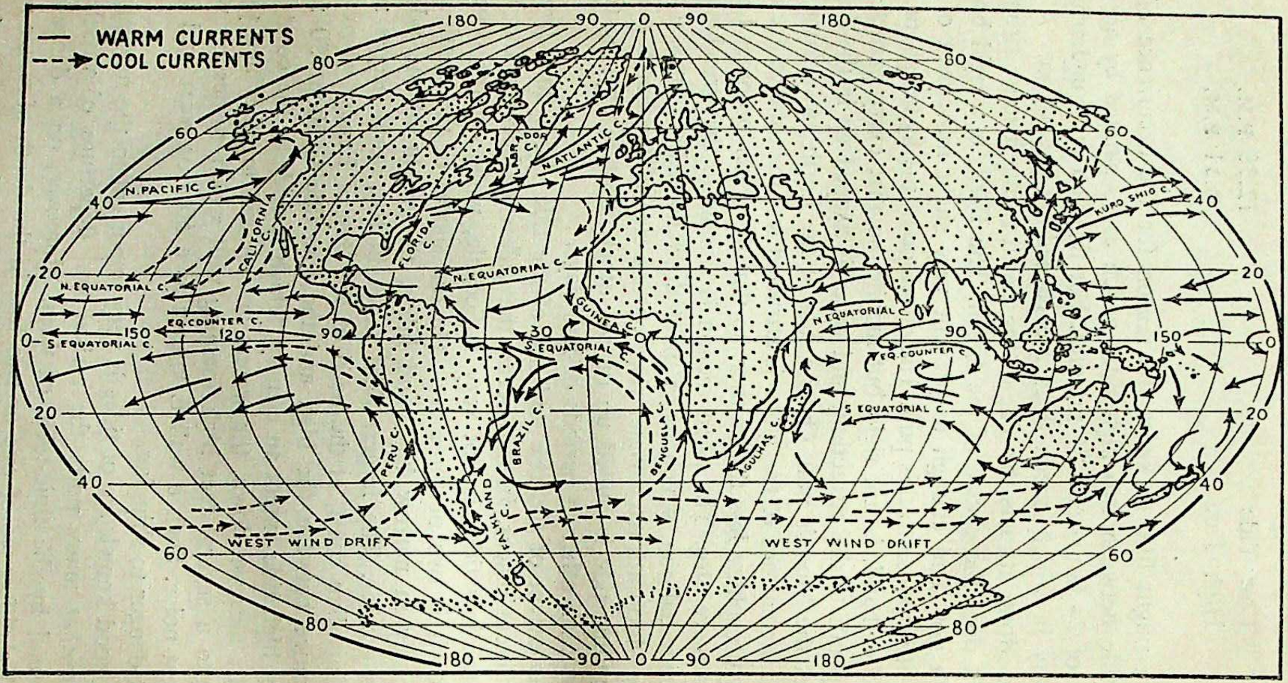


Fig 21—OCEAN CURRENTS

of a government to provide time-tables showing the fluctuations at the main ports for every hour and every day for as much as a year ahead.

Ocean Currents

Besides the waves and the tides, ocean currents also involve the movement of the surface waters of the oceans. They are mainly caused by the winds, but their direction is determined not only by the prevailing winds but also by the shape of the land masses which they encounter as well as by the deflection caused by the rotation of the Earth. The temperature of the ocean water decreases as we go from the Equator to the Poles, and such differences in temperature do produce a surface flow of warm water from the Equator to the Poles, and an under-surface flow of cold water from the Poles to the Equator. The rate of this movement, however, is very slow, so that temperature differences cannot be accepted as the main cause of ocean currents.

When a current flows from a warm to a cool area it is called a warm current. Conversely, if it flows from a cold to a warm area it is described as a cold current.

The North-east and the South-east Trades, which are strong and steady winds, drive the surface waters in the Equatorial regions westward, thus causing Equatorial Currents. These currents after travelling across the oceans encounter projecting land masses and split up. Their main branches then proceed Polewards, but the minor branches drift back eastwards along the Equator, and are known as the Counter Equatorial Currents. The main branches, on reaching the regions of the Westerlies, turn eastwards because of the Earth's rotation. Later, on striking the western margins of the continents, they generally turn towards the Equator and finally join the Equatorial currents. We can see from the above description that the movement of the main currents is clockwise in the northern hemisphere and anti-clockwise in the southern hemisphere.

If the moving water in a current is of considerable depth, forming, as it were, a river in the ocean, the current is known as a stream, but if the moving water is broad, shallow and sluggish it is called a drift. The central part of the ocean around which

currents circulate becomes an area of calm water, called the *Sargasso Sea,* in which seaweeds accumulate to such an extent that the passage of ships becomes difficult.

There is a great correspondence between the winds and the currents in different oceans. In this connection, the Indian Ocean is most remarkable, for in this ocean the direction of the currents is completely reversed with the seasonal changes in the direction of the monsoons.

Ocean currents are of considerable importance to us in several ways. They influence the great sea routes along which much of the world trade is carried on. They modify the climates of the lands along which they pass. The cold Labrador Current, for example, chills the Atlantic coast of North America, while the Gulf Stream is responsible for the mildness of the climate of Western Europe and that of a large part of North America's eastern coast. In fact, the Gulf Stream is aptly described as the "aorta of western civilization on both sides of the Atlantic Ocean".

Let us imagine the changes that would take place if the Gulf Stream were to disappear. In the absence of the opposition offered to it by the Gulf Stream, the cold Labrador Current would push southwards, with the result that much of the American coast would become icebound. The already meagre supply of warmth and rain in northern Europe would be further reduced and the whole area would turn into a cold desert. As a result of decreased rainfall, the ice deposits on the Alps would be reduced and these mountains, relieved of their load, would gradually rise up, causing intense earthquakes and large-scale crustal movements in Europe, which would produce repurcussions in other parts of the world.

CHAPTER SIX

THE ATMOSPHERE

Introduction

MEN are like fish, for they live in a sea—right at the bottom of it. This sea is of air but it is far deeper than the deepest ocean. This sea of the empty, vast and wandering air envelops the Earth and accompanies it on its journey along the path around the Sun.

We are generally not fully conscious of the atmosphere around us. Usually we do not take any notice of the air we breathe in. Often we do not notice the gentle breeze that caresses our face. Sometimes, however, the atmosphere makes its presence felt through the mighty gales and destructive thunderstorm which uproot trees, destroy crops and pull down houses.

The atmosphere is one of the necessary conditions for the existence of life on our planet. No living organism of the animal or the plant kingdom can survive without the envelope of the atmosphere.

How is it that the Earth has been able to retain its envelope of atmosphere through the billions of years of its existence? If the atmosphere is made of gases and if gases tend to spread over as large an area as possible, how is it that the gases of our atmosphere have not escaped into cosmic space? What is that force which has always kept the canopy of air clinging to the Earth? Well, that force is the gravitational pull of the Earth. In order to counteract this pull and fly away from the Earth, the molecules of air need to attain a velocity of about 7 miles per second. Normally, however, they do not acquire such a speed, with the result that their movement, like that of a chained animal, is restricted to a particular zone surrounding the Earth.

As noted earlier, we are indebted to the atmosphere for all forms of life on our planet. Stellar bodies with smaller mass have a thinner atmosphere or no atmosphere at all. The Moon, for example, is just a lump of naked rocks devoid of atmosphere and hence of life. Small in size as it is, gravitational pull has not been sufficient to retain the atmosphere which may have enveloped

it in the early stages of its life. Since a molecule of air needs to acquire a speed of only 1.25 miles per second to escape from the gravitational pull of the Moon, we find that the Moon does not possess any atmosphere at all.

Venus, on the other hand, is almost as big as our planet. It is not surprising, therefore, that it is clothed in a dense atmosphere. The beauty of Venus, which has inspired so many myths and legends, is due to its atmosphere. The reason why Venus appears so beautiful is that its clouds reflect the sunlight which this planet receives.

Composition of the Atmosphere

The atmosphere, as everyone knows, is chiefly made up of air. But what is air? The answer to this question is not simple. Since the very beginning of civilization men had been trying to understand the nature of air, but it was only recently that they were able to find the real answer.

To the ancient philosophers, air was one of the four elements of which the universe was made, the other three being earth, water and fire. One of the Indian philosophers of antiquity was so much impressed by the ethereal nature of the air that he considered it to be the primal substance of which everything else was made. The idea that air was an element had the authority of Aristotle behind it, and this idea continued to be accepted until 1772, when Scheele rejected it and proved that air is a mixture of several gases. Nine years later, Cavendish made a scientific analysis of the constituents of air, and he came to the conclusion that it was composed of oxygen and nitrogen, the proportion of the two being 20.83 and 79.17 respectively. Later researches proved that Cavendish's analysis was nearly correct. However, it was found that there are a number of other gaseous elements in the air, so that the actual composition of the air includes the following gases in the proportions noted against them:

Oxygen	20.95	Per cent by volume
Nitrogen	78.09	
Carbon dioxide	00.04	
Rare gases	00.94	

Oxygen, a colourless gas, is a constituent of the air which, more than any other gas, should be regarded as the breath of life. Without oxygen the chemical processes which sustain life would not be possible. Man can live for some time without food, even without water, but he cannot live without oxygen for more than a few minutes. The presence of oxygen is necessary for the metabolic processes in human body—processes which are essential to life.

The other important constituent of the air is nitrogen. Although it forms the great bulk of the air we breathe in, Lavoisier called it "azote" (lifeless), for it alone cannot support life. Nevertheless, nitrogen in its own way contributes to the maintenance and growth of living organisms. Without sufficient nitrogenous content, the soil loses its fertility so that the growth of plants is retarded. That is why we use nitrates and salts of ammonia to enrich the nitrogenous content of the soil.

Even though the amount of carbon dioxide in the air is small, it has a significant role to play. It helps plants to grow, for they manufacture their food out of carbon dioxide and water. It also helps to regulate the rate of breathing in animal organisms. The carbon dioxide which the animals exale is absorbed by plants and its oxygen constituent is later released into atmosphere. Thus plants and animals work together to maintain the balance of these gases in the atmosphere.

The rare gases are present only in very small quantities in the air. They are also called "inert" gases because chemically they do not combine easily with other gases. The most important inert gases are argon, neon, krypton, xenon and rodon. Of these, we are most familiar at least with neon, for we see the brilliant crimson glow of neon electric tubes which are used for illuminated advertising in the cities.

A peculiar constituent of the atmosphere is ozone, each molecule of which is built up of three atoms of oxygen. Ordinarily, in a molecule of oxygen the atoms[1] cling together in pairs, but sometimes oxygen molecules break up and the atoms thus released combine with other molecules of oxygen to form ozone, which has a strong smell and causes an increased rate of chemical activity. The amount of ozone in the Earth's atmosphere is so

[1] For a detailed discussion on atom, refer to *The Universe and the Atom*, a publication of the same Project.

small that if all of it were to be collected in a uniform layer clinging to the Earth, the thickness of this layer would not be more than 1/8th of an inch. Yet, this small amount is extremely useful for us, for it absorbs at least 5 per cent of the solar heat reaching the Earth. Without any ozone in its atmosphere, our planet would have been a much hotter place.

In addition to the gases described above, the atmosphere includes certain non-gaseous substances. Firstly, there is water in the form of vapour or liquid drops or particles of snow and ice. Secondly, there are solid substances of organic or inorganic origin.

The microscopic solid particles of inorganic origin, which remain suspended in the air, may be described as dust. These dust particles are derived from various sources such as dust-storms, meteoric ashes, wind-blown salt particles from the seas, volcanic eruptions and smoke from burning fire or factories.

Dust particles are largely confined to the lower layers of the atmosphere and their amount decreases as we go upwards. Their horizontal distribution also is far from uniform. For example, air from the areas in mid-ocean contains 500 to 2,000 dust particles per cubic centimeter, while in dusty cities as many as 100,000 particles may be present in one cubic centimeter.

Solid particles of organic origin which may be found in the atmosphere include pollen from plants, various kinds of bacteria[1] and spores of fungi.

It must be clear now that the air is not such a simple thing as Aristotle thought it to be. It is neither an element, nor even a compound, but a complex mixture of a number of gases in which a considerable quantity of non-gaseous substances may also be present.

If the air is a mixture, how is it that its composition is fairly uniform throughout the lower regions of the atmosphere? This is because the atmosphere is being constantly churned all the time. Had the atmosphere been perfectly still, lighter gases would have ascended to the upper strata. But our atmosphere is restless.

[1] For a detailed discussion on bacteria, refer to the *Story of Life*, another publication of the same Project.

Structure of the Atmosphere

Until recently, our knowledge of the atmosphere was restricted only to those of its layers which are adjacent to the Earth. The first expansion of knowledge came when balloons and aeroplanes were used to explore the upper strata of the atmosphere. Now we live in the age of man-made satellites which can probe into the depths of space and send us valuable information regarding the conditions prevailing there.

Vertically, the atmosphere can be divided into three layers, namely, the *troposphere,* the *stratosphere* and the *ionosphere.*

The lowest layer, at the bottom of which we live, is the troposphere. It is the densest part of the atmosphere and possesses about 80 per cent of the total mass of air in the whole atmosphere. From the sea level it extends upwards up to 11 miles over the Equatorial regions and up to 4 miles at the Polar regions. From the sea level as we ascend vertically in the troposphere the temperature decreases. This rate of decrease, called the "lapse rate", is about 1°F per 300 feet. The temperature goes on decreasing until we reach the tropopause which is the zone of transition separating the troposphere from the stratosphere. The temperature of the tropopause is about 70° C.

Water-carrying clouds are normally restricted to the troposphere. It is in fact the "weather sphere" because all the weather phenomena (clouds, rain, snow, hail, lightning, thunder and so on) occur in this layer. You can see why most of the aviation risks are encountered in the troposphere.

Above the tropopause, extending upwards for more than a hundred miles, is the stratosphere. It is a region of eternal quiet, with a constant temperature of about 55° F., and free from dust, storms and clouds.

It should be realized that at heights of more than twentyfive miles from the surface of the Earth the gases of the atmosphere are in an extremely rarefied or thin state. Even at altitudes of five miles the air is so rare or thin that the lungs cannot absorb a sufficient quantity of oxygen to support human life.

A peculiar phenomenon has been noted at about 12 to 15 miles above the sea level. Here, the atmosphere contains a large amount of ozone, or active oxygen gas, and above this, at an elevation

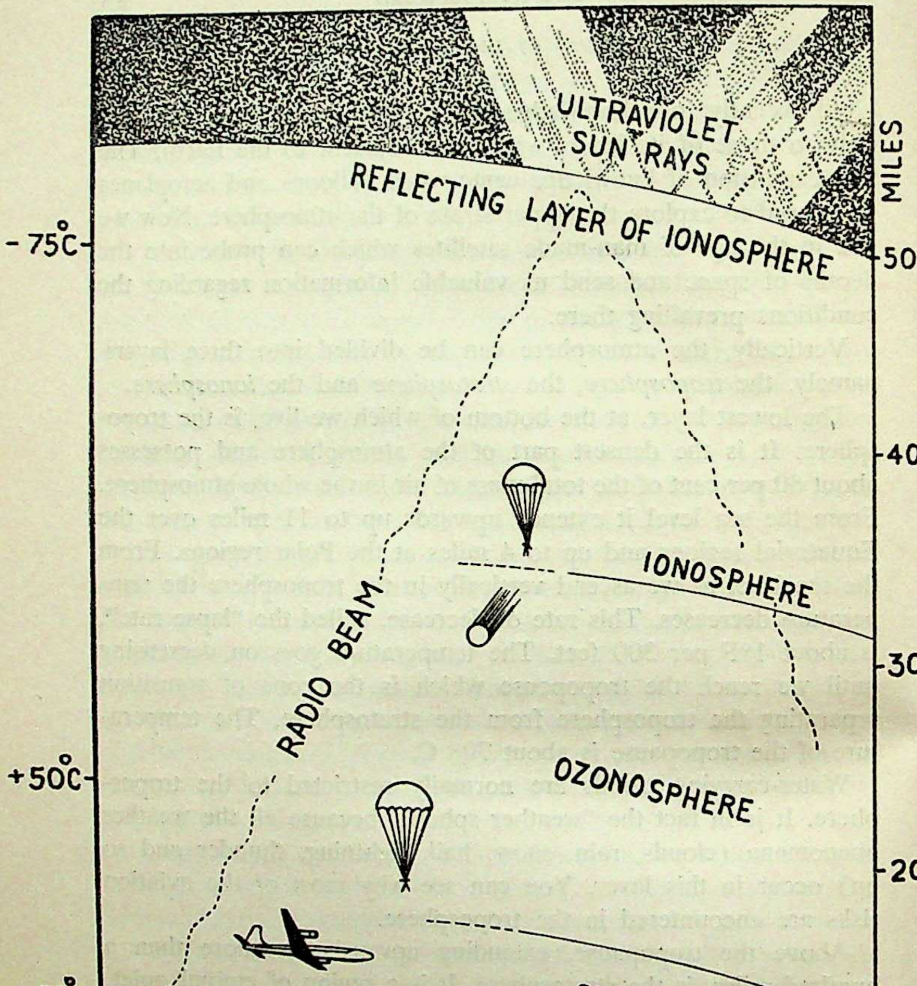


Fig. 22—LAYERS OF THE ATMOSPHERE

of about 50 miles, is a layer which tends to reflect radio waves, making long distance radio broadcasting possible. This layer is especially active in the day-time, which accounts for the fact that radio stations, particularly short-wave stations, cover a greater range during the night than during the day.

The characteristic feature of the ionosphere (the last layer of the atmosphere) is that the air in it conducts electricity. To understand this phenomenon, you must first understand the structure and behaviour of gases.

Gases are made up of molecules which are so small that one cubic centimetre of air contains about 27,000,000,000,000,000,000 molecules of various gases. Molecules are made up of atoms, which consist of still smaller particles called electrons, protons and neutrons. Electrons (which are negatively charged) revolve in orbits round a heavy nucleus which consists of positively charged protons and neutral neutrons. Thus, while the nucleus has a positive electric charge, the electronic shell has a negative charge. The number of electrons in an atom is always equal to the number of protons. That is why an atom as a whole is neutral and so is a molecule, for it is made of atoms.

Now, let us suppose that an atom or a molecule loses one or several of its electrons. Obviously, it will no longer be electrically neutral; it will have a positive charge. If the released neutron attaches itself to an atom or a molecule, the latter will develop a negative charge. Any molecule of gas which possesses a free electron has the property of conducting electricity.

The ionosphere contains free electrons which produce ions (positively or negatively charged atoms). The ionosphere, therefore, conducts electricity. The process of ionization (separation of an electron from the atom) is due to the ultra-violet rays from the Sun. The ionosphere, in other words, absorbs the ultra-violet rays of the Sun and saves the organisms on the surface of the Earth from the harmful effect of these rays.

The ionosphere is conventionally divided into four sub-layers: D, E, F, and F_2. The sub-layer E is of great significance, for it reflects specific wave-lengths of the radio scale. In other words, it acts as a mirror and sends the radio waves back to earth instead of allowing them to escape in cosmic space.

The most fascinating phenomenon associated with the iono-

sphere is the occurrence of *aurora polaris,* which are long, waving streamers of light in the night sky in high latitudes. Auroras are generally silvery white in hue but not infrequently they display a wide range of colour. In Greek mythology, Aurora was the goddess of dawn and every morning she went before the chariot of Apollo (the Sun-god), scattering flowers and drawing with her rosy fingers the veil of night. The scientific theory, however, is that auroral displays are caused by streams of charged particles from the Sun which make the gases of the ionosphere glow.

The precise limits of the ionosphere are not known, but with the help of artificial satellites it is gradually becoming possible to form a clearer picture of the outer zones of the atmosphere. We know, for example, that at about 400 miles from the Earth's surface is the xenosphere where the gravitational pull of the Earth becomes so weak that molecules of gases escape into inter-stellar space. The xenosphere is believed to extend up to 500 miles.

Pressure of the Atmosphere

To describe something which has very little weight, we say: it is as light as air. Air is certainly lighter than water, but this does not mean that it has no weight. If it has weight, it must exert pressure.

The pressure exerted by the air is enormous. It is about 15 lb. on every square inch. In other words, a human body lives under a pressure of nearly 15 tons or a weight equal to that of three elephants. We are not crushed by this pressure because the blood and tissues of our body exert an equal amount of pressure against the atmosphere.

The fact that air exerts pressure can be proved by a number of simple experiments. For example, take a tin can partly filled with water. Let the water boil so that much of the air in the can is pushed out by steam. Tightly cork the can and cool it, so that the remaining steam is converted into water, and a vacuum is created above the water level. At this stage a queer thing will happen. The can, with a vacuum inside it, will crush in under the pressure of the surrounding air.

This experiment sounds very simple. Yet, it took thousands of

years for civilized man to learn the fact that the air has weight and that it exerts pressure. Galileo was the first scientist to discover this fact, and one of his disciples, Torricelli, devised the first instrument, namely, the barometer, to measure atmospheric pressure.

The principle on which a barometer works is rather simple. It had been demonstrated by Galileo that an ordinary pump could not raise the water more than 32 feet above the level of water in a well. Torricelli hit upon the idea by which air pressure could be measured. Knowing that mercury is 13 times heavier than water, he argued that if the pressure of air was enough to push water to a height of 32 feet, then the same pressure of air should be sufficient to push a column of mecury one-thirteenth as high, or about 29.5 inches. Torricelli's next step was to make a glass tube, plugging one end to make it airtight and leaving the other open. He then filled the tube with mercury and placed it upright with the open end in a basin filled with mercury. The column of the mercury fell until it was only 29 or 30 inches high, leaving a vacuum at the top of the tube. The level of mercury at the tube then rose or fell according to the changes in the atmospheric pressure, that is to say, the changes in the weather.

Torricelli constructed his barometer in 1643, but even after the passage of three centuries the barometers which we use today are only the refined forms of Torricelli's instrument.

Atmospheric pressure is far from constant either in time or in place. It decreases as you go up in the atmosphere. The reason is obvious: as you go up, you leave a layer of air beneath you, with the result that this layer does not exert its pressure on you. The fall in pressure with height is comparatively rapid in the lower regions of the atmosphere. In general, it may be said that the pressure of air decreases by 1/30th of its value with an increase of 900 feet in altitude. Other things remaining the same, if the pressure at sea level is 30 inches, then it will be 29 inches at 900 feet and 28.3 inches at 1,800 feet above the sea level.

The principle that altitude and atmospheric pressure are inversely related has made possible the invention of useful instruments such as the altimeter or the aneroid barometer.

Atmospheric pressure does not change only with altitude but also from locality to locality and from time to time. London,

San Francisco, Calcutta and Sydney are all situated at sea level but at any given time the barometric readings at these places are likely to be considerably different. These differences are due to several factors, but the most important of them all is the difference in temperature. When a mass of gas is heated, it expands and its density is lessened so that the pressure it exerts is reduced. Hence, temperature and pressure are inversely related; the higher the temperature, the lower is the pressure and vice versa.

You are aware that the hottest part of the Earth is the Equatorial belt roughly between 5° N. and 5° S. of the Equator. This high temperature belt is naturally a low pressure area. It is a region of dead calm or of very light and variable winds. The boats of the pre-steam age were bacalmed in this region, so that the sailors called it the "doldrums", which is an old word meaning dull or stupid. The regions around the North Pole as well as the South Pole being cold areas have high pressure. One might expect that the atmospheric pressure would gradually decrease from the Equator towards the two Poles. But it is not so, for there exist High Pressure Belts at latitudes 30-40° both in the northern and the southern hemispheres. These belts occur because the great wind currents which are drawn towards the Equatorial Low Pressure rise up and then travel pole-wards, descending between 30-40° latitudes, and causing High Pressure areas in those latitudes. These are regions of calm weather and light winds. The sailors named the belt of calm in the northern hemisphere as the "horse latitudes". There is a tragic story behind this. Before the invention of steamships sail-boats used to carry horses from Jamaica to the British Isles. When the boats reached this dreaded area of calm, they were often stuck because of lack of winds. Hence, horses had to be thrown out of the ship to make it lighter.

Atmospheric pressure does not remain constant at any place throughout the year. It changes with seasons—gradually becoming higher during the winter and lower during the summer. It does not remain constant even during the course of any single day. To sum up, atmospheric pressure varies from place to place, from height to height, from season to season, and from hour to hour.

Air Movement

Of all the mysteries of nature, the movements of air have long been amongst the most puzzling ones. "The wind bloweth where it listeth, and thou hearest the sound thereof, but canst not tell whence it cometh and where it goeth." These words of the Bible were said when little was known to explain air movements. Today it is known that all winds are caused by difference in atmospheric pressure. You have already seen that there are a number of permanent pressure belts encircling the globe. Consequently, you may expect a permanent circulatory system of winds on the surface of the Earth.

The winds blowing from the Sub-tropical Highs to the Equatorial Lows are called the Trade Winds. These winds, however, do not blow directly towards the Equator. They are deflected by the Earth's rotation, so that they blow from the north-east in the northern hemisphere and from the south-west in the southern hemisphere.

The winds which blow from the Sub-tropical Highs towards the Poles are known as the Westerlies. However, the Westerlies do not blow directly from the west but from the south-west in the northern hemisphere and from the north-west in the southern hemisphere. They are not as steady as the Trade Winds, and are associated with a good deal of cyclonic disturbances, especially in the southern hemisphere where the vast expanses of ocean surface allow them free play.

The winds which blow from the Poles outwards are called Polar Winds. They blow from the north-east in the northern hemisphere and from the south-east in the southern hemisphere.

The pressure belts as well as the winds described above would have assumed a regular and permanent pattern if the surface of the globe had been homogeneous, that is to say, entirely made of either water or land. But since the Earth's surface is differentiated into land and water, the permanent pressure belts as well as the wind systems tend to be disturbed. As a rule, land masses warm up and cool down more rapidly than water bodies, and the difference in the temperatures of the two leads to differences in atmospheric pressure, which causes new winds to blow.

If the Sun's rays always fell vertically on the Equator, the pres-

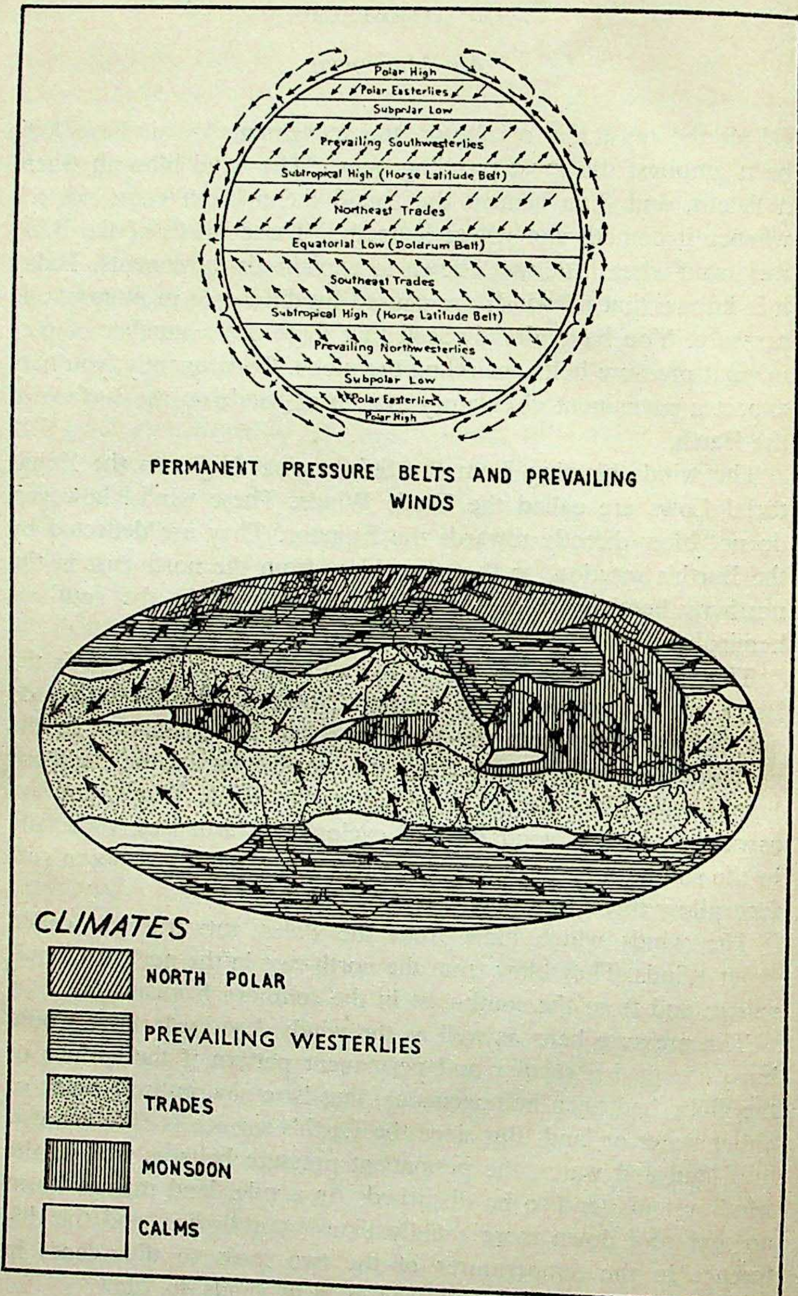


Fig. 23—WINDS & CLIMATES

sure and wind belts of the globe would remain unchanged throughout the year. But while during the northern summers the Sun shines almost vertically over the Tropic of Cancer, during the southern summers its rays fall almost perpendicularly over the Tropic of Capricorn. The shifting of the Sun's position results in the migration of pressure belts. Hence, while the Equatorial Low is a few degrees north of the Equator during July, it is a few degrees south of the Equator during January. All other belts show similar migrations and, as a result, the permanent wind systems are considerably modified.

The most notable of these modifications occurs on the eastern margins of the continents in the tropical and sub-tropical areas of the northern hemisphere. This modification causes the seasonal Monsoon Winds.

Let us see how the Monsoons are caused.

Eurasia which is a vast continental mass is situated in the northern hemisphere. It is surrounded by the Pacific Ocean in the east, the Indian Ocean in the south and the Atlantic Ocean in the west. In winter, the air over the Eurasian continent cools down and becomes heavier than the air over the adjacent oceans. As a result, a high pressure centre is formed in the heart of the continent and winds are expelled from this centre towards the oceans. In South-east Asia, the cold sea-ward winds are known as the Winter Monsoons.

During the summer season, however, the position is reversed. The land mass of Eurasia is warmer than the surrounding oceans, so that its interior develops a low pressure to which winds are drawn from the oceans. The south-easterly landward winds which blow over South-eastern Asia during this season are known as the Summer Monsoons. They bring the much needed rains to the parched fields and put an end to the spell of hot and dry summer.

Apart from the permanent and seasonal winds described above, there are a number of local winds which are caused by local variations in pressure. The most familiar local winds are the land and sea breezes. They are produced by the unequal heating of land and water masses. During the day land becomes warmer than the sea, so that its lighter air rises up. The space vacated by this air is filled by air currents from the seas. These cool re-

freshing surface currents are known as *sea breeze*. The sea breeze starts blowing in the forenoon. Then, a reverse process begins in the late afternoon. The land begins to cool more rapidly than the neighbouring seas and its atmospheric pressure becomes greater over the land than over the seas. As a result, winds begin to blow from the land towards the sea. These are called *land breezes* and are felt during late evenings and nights. The land breezes as well as the sea breezes are shallow winds and their domain does not extend beyond a few miles on the seaward or the landward side of the coast.

In addition to the winds described above, there are certain other atmospheric disturbances which deserve to be mentioned. The most important of these disturbances are known as cyclones or depressions. A cyclone shows a pattern of pressure distribution in which there is a low pressure area in the centre, with the pressure increasing outwards. Winds tend to blow spirally inwards, and the convergence of surface currents from all sides leads to an ascent of air in the centre of the cyclone. The cyclones of the temperate regions of the world usually have a diameter of 300 to 500 miles—even up to 2,000 miles in some cases. Tropical cyclones, on the other hand, cover smaller areas, and are usually 50 to 200 miles in diameter.

An anticyclone is an area of high pressure with the pressure gradually decreasing outwards on all sides, so that the winds blow outwards from the high pressure centre. Unlike cyclones, the anticyclones do not travel in well defined paths.

Just as the steepness of the slope of a land determines the velocity of a river, so do the differences in atmospheric pressure determine the velocity of winds. If the pressure gradient is steep, that is, if the difference between the pressure per unit of length is large, winds blow with great strength. On the other hand, if the pressure gradient is gradual, winds are light. Winds of different velocities are known by different names and they can be identified by the motions they cause in certain objects such as tree leaves or smoke. The Beaufort Scale recognizes the types of winds as given in Table 6.

TABLE 6

Beaufort No.	General Description	Specification	Velocity (miles per hour)
0	Calm	Smoke rises vertically	Less than 1
1	Light air	Wind direction shown by smoke drift but not by vane	1- 3
2	Slight breeze	Wind felt on face; leaves rustle; ordinary vane moved by wind	4- 7
3	Gentle breeze	Leaves and twigs in constant motion; wind extends light flag	8-11
4	Moderate breeze	Dust, loose paper and small branches are moved	12-16
5	Fresh breeze	Small trees in leaf begin to sway	17-22
6	Strong breeze	Large branches in motion; whistling in telegraph wires	23-27
7	Moderate gale	Whole trees in motion.	28-34
8	Fresh gale	Twigs broken off trees; progress generally impeded	35-41
9	Strong gale	Slight structural damages occur; chimney pots removed	42-48
10	Whole gale	Trees uprooted, considerable structural damage	49-56
11	Storm	Very rarely experienced; widespread damage	57-67
12	Hurricane		Above 68

Atmospheric Humidity

A wet handkerchief when hung in the open becomes dry, that is to say, the particles of water which kept it moist pass into the air in the form of vapour.

Whenever a body of water and a body of air come in contact

with each other, an interchange of water particles takes place. When a body of air is dry it goes on absorbing molecules of water until a point is reached when it holds as much vapour as it can. That point is known as the *saturation point,* and the air in such a state is known as *saturated.*

The amount of water vapour which a cubic foot of air can hold depends on the temperature of the air. As a body of air becomes warmer, its capacity to hold water becomes greater. Table 7 gives the number of grains of water in one cubic foot of saturated air at various temperatures:

TABLE 7

Temperature in F. degrees	30	32	40	50	60	70
Grains of water vapour per cubic foot	2.21	2.37	3.09	4.28	5.87	8.00

Table 7 shows that it is not the actual amount of water vapour in the air which makes us feel its wetness or dryness. The proportion of the amount present to the maximum amount possible at a specific temperature is of greater significance as far as the feel of the air is concerned. In other words, the important question is: How thirsty is a body of air?

You will be surprised to know that the air over the Sahara Desert contains more vapour per cubic foot than the air over England on a winter day. But the Sahara air feels dry while the English air feels moist. This is because the temperature of the former is considerably higher than that of the latter.

In the light of the above, meteorologists differentiate between the "absolute" and the "relative" humidity of the atmosphere. Absolute humidity may be defined as the mass of water vapour per unit volume of air. It may be expressed either as the number of grains' weight per cubic foot of air or as the number of grams per cubic centimetre. Relative humidity, on the other hand, may be defined as the ratio of the actual quantity of water vapour in a given volume of air to the maximum possible quantity in the same space at the same temperature. It is expressed as a percent-

age. This percentage must always be more than zero because even the direct air in nature is not completely without moisture. If the air is over-saturated, the relative humidity is expressed as over 100.

One of the simplest ways of finding out the quantity of water vapour present in the air is through the determination of dew-point. Dew-point is the temperature at which begins the condensation of water vapour in the air. In other words, it is the temperature of saturation. After the dew-point has been determined, the total amount of water vapour in the air can be easily found out with the help of a table. If, for example, the dew-point is 80° F, each cubic foot of air should contain 8.00 grains of water-vapour.

When a mass of air is cooled below the dew-point, the surplus vapour usually condenses. Any mass of air which is cooled below its dew-point without the occurrence of condensation is said to be over-saturated. Over-saturation takes place in the atmosphere on a very small scale, while condensation of water vapour is the general rule.

If the dew-point is above the freezing point, water vapour condenses into liquid droplets of about 1/500th inch diameter. It is interesting to note that these droplets remain in their liquid state even if the temperature falls several degrees below the freezing point, the only provision being that they should not be distrubed, for as soon as they are disturbed they freeze.

If the temperature of saturation is below the freezing point, water vapour condenses into minute ice crystals. These crystals have a tendency to aggregate and form snowflakes.

When condensation takes place not in the air itself but on the surface of some solid body which comes in contact with it, the result is the formation of dew and hoar-frost.

Water vapour condenses into liquid drops of dew if the dew-point is above the freezing point. On the other hand, if the dew-point is below the freezing point, condensation results in the formation of *spicules* (small sharp-pointed bodies) of ice, which are known as hoar-frost.

If a body of air is cooled not only along the surface of some cold object but throughout its mass, condensation takes place in the air itself, leading to the formation of small droplets of water

which float in the air for a fairly long time. When this phenomenon occurs nearer the Earth's surface, fog or mist is formed, but clouds are produced when it occurs higher up in the troposphere.

Do the water drops forming a fog fall to the ground? They do, although rather slowly. Their very small size hampers their fall and for a long time they remain suspended in the air. Sometimes an upward current of air may prevent their fall altogether.

A body of air near the Earth's surface may be cooled throughout its mass in a number of ways. For example, it may be cooled by coming in contact and mixing with a cooler mass of air. In such circumstances, condensation takes place but only on a very small scale. The reason is obvious. As a result of the coming together of the two masses, the warm air cools but the cool air warms. While the capacity of the former to hold moisture decreases, the capacity of the latter to hold moisture increases.

An air mass may be cooled if instead of its temperature falling down, its moisture content is increased sufficiently. In such a case the air would become saturated and condensation of surplus water vapour would take place, resulting in the formation of fog.

Masses of air close to the Earth's surface may be cooled below the dew-point as a result of radiation. In the absence of a cloud cover, the Earth tends to cool rapidly by radiating its heat. The process begins with the approach of sunset. The temperature of the layers of air which are adjacent to the Earth's surface is also lowered. If the horizontal movement of air in any area which is radiating heat is weak, a thick layer of air above the ground may be sufficiently cooled to enable the formation of fog or mist.

If a mass of warm and moist air moves along the Earth's surface to a considerably colder region, its temperature may go down below the dew-point, resulting in condensation on a large scale in the lower layers. This may happen, for example, if warm and moist air passes over a cold ocean current, as is the case with the formation of the Atlantic fogs off New Foundland.

The essential mechanism responsible for the formation of clouds is the same as in the case of fog or mist. A cloud is a mist formed higher up in the troposphere.

Rain, Snow and Hail

The sky is overcast. High above us dark and silvery clouds are wandering about. The farmer looks at these clouds hopefully, but not a single drop of rain falls. The formation of clouds, by itself, is not enough for the rain to fall.

Clouds are made up of innumerable water drops of very small size, even smaller than the little drops in a drizzle. The drizzle drops have an average diameter of 1/100th to 1/50th of an inch, while the rain drops are bigger and vary from 1/25th to 1/5th of an inch in diameter. Cloud droplets float in the air; drizzle drops drift downwards; rain drops fall to the ground.

Precipitation is, therefore, essentially the process of cloud droplets coalescing or uniting together to form drizzle drops and rain drops. Why do the cloud droplets coalesce or unite? The science of meteorology has not yet been able to give a fully satisfactory answer to this. The theory propounded by Bergeron, a Norwegian scientist, is that the process of fusion depends on the co-existence of water droplets and ice crystals in the same cloud, so that evaporation takes place from the water droplets and condensation occurs on the ice-crystals, which consequently increase in size and become heavier. As they fall through the cloud, they become still heavier and bigger by further condensation and mutual fusion. Bergeron's theory has been confirmed by artificial "rain making" experiments in the United States, Australia, and the Soviet Union. It has been discovered, for example, that snow can be made to fall from the base of a cumulus cloud, if a small quantity of fine particles of dry ice (solid carbon dioxide) is dumped into it.

In addition to rainfall, precipitation may occur in two other forms: snowfall and hailstone.

When the dew-point of the air is insufficiently low, water vapour condenses into tiny ice crystals instead of water droplets. These crystals tend to aggregate or unite for reasons not yet fully known. Falling snow flakes are aggregates or combinations of such crystal-aggregates.

As for hailstones, they are formed by the freezing of raindrops. If a raindrop, formed at the lower level of a cloud, is carried to the higher strata by vertical currents, it freezes and turns into

a pellet or pill. This pellet becomes a nucleus or centre around which other ice crystals are collected. It then falls down through the cloud and partially melts in this process. Some vertical current of air may once again carry it to the higher strata, so that the whole process is repeated. The pellet goes on increasing in size and ultimately is able to fall to the ground in the form of a hailstone.

As we have seen above, rain is caused by the wholesale cooling of air, leading to the coalescing of cloud droplets into rain drops. There are two principal methods by which such a cooling is brought about. Firstly, by the horizontal movement of a body of air from warmer to cooler latitudes; secondly, by the vertical movement of a body of air to greater altitudes where both temperature and pressure are less. On the contrary, if a body of air moves either from a cool to a warm area or from a high to a low region, its capacity to pick up moisture becomes greater.

Keeping the above in view, we examine the diagram showing the distribution of pressure and wind belts on the globe. In this diagram it is easy to distinguish the regions where the winds blow towards the Equator from the regions where they blow towards the Poles. The Westerlies blow from warm to cool regions, while the Trades blow from cool to warm regions. Ordinarily, therefore, the Westerlies are rain-bearing winds while the Trades are dry winds.

In the same diagram you can see some belts where the air is ascending and some where it is descending. As a rule, low pressure belts must be areas of ascending winds and high pressure belts must be areas of descending winds. The former belts are therefore characterized by copious rainfall, while the latter are generally dry.

Had the surface of the Earth been homogeneous, i.e., composed either entirely of land or entirely of sea, the distribution of rainfall would have been determined by the two factors mentioned above, and would have been fairly simple, that is to say, in the form of belts running parallel to the Equator. The presence of land and sea, however, complicates the picture. For obvious reasons, the air above the oceans contains a larger amount of vapour than the air above the land. In normal conditions, therefore, there is more rainfall over the sea than on the land. Away

from the oceans, the amount of rainfall gradually decreases.

The directions of winds introduce further complications. The rainfall systems on the eastern margins of the continents differ from the system on the western margins. In the region of the Westerlies, for example, the western margins receive rain-bearing winds directly from the oceans, so that they have a sufficient amount of rainfall. On the other hand, winds which reach the eastern margins after journeying across a continent are relatively dry.

Further modifications are introduced in the rainfall system all over the globe because of the shifting of the pressure belts with the shifting position of the Sun. The extension of the shift varies in different parts of the world, depending upon the latitude and the topography of the land. Roughly speaking, the shifting or migration of the belt is about 8° north and south latitudes.

Taking all the above factors into consideration, the world can be roughly divided into the following rainfall regions:

1. *Equatorial Regions*: These lie between 5° N. and 5° S. latitudes. As a result of the ascending currents of air, heavy rainfall occurs in them throughout the year. There are two periods of very heavy rainfall during the course of a year, and these coincide with the period when the Sun is overhead.

2. *Tropical Grasslands*: These extend from the Equatorial Regions to the Tropic of Cancer as well as to the Tropic of Capricorn. Most of the rain falls during the summer season, while the winters are dry.

3. *Monsoon Regions*: These are situated on the eastern margin of the continents in the same latitudes as the Tropical Regions. They have a long dry season, but a pronounced rainy season in late summer. The contrast between the wet season and the dry season is very distinct.

4. *Hot Deserts*: These deserts cover the western margins of continents from 15° to 30° north as well as south latitudes. The Trades blow as off-shore winds throughout the year. The climate is arid or semi-arid. If there is any rainfall at all, it occurs in the summer months.

5. *Mediterranean Regions*: These regions lie on the western margins of the continents between 30° and 40° latitudes in both the hemispheres. Rainfall takes place during winter when these

regions are under the influence of the Westerlies. Summers are dry because the prevailing winds in this season are the dry Trades.

6. *Eastern Marginal Lands*: These regions are situated in the same latitudinal strip as the Mediterranean regions, but on the eastern margin of the continents. Although rainfall occurs throughout the year, most of it is brought by the Monsoon winds during the summer season. Winter rains are caused by the depressions crossing over from the temperate regions.

7. *Temperate Continental Regions*: These regions are in the temperate latitudes and cut off from the oceanic influences. No part of the year is completely dry, but most of the rainfall occurs in spring or early summer.

8. *Cool Temperate Marginal Regions*: These regions are situated beyond the 40th parallel within the temperate latitudes. Rainfall occurs throughout the year. While the western margins have a winter maximum, the eastern margins get most of their rainfall in summer.

Air Masses and Fronts

It was only in the first decade of the twentieth century that the first attempts were made by meteorologists to study air masses as distinct units. This was a very significant step, and it led to the opening of a new chapter in the science of meteorology.

The various weather phenomena are due to the circulation of large masses of air. An air mass may be defined as a large body of air which in its horizontal extent has more or less uniform physical properties, particularly temperature and humidity. Let us note that a body of air which remains in contact with the surface of the Earth for a fairly long time gradually acquires certain properties (temperature, humidity, etc.), and tends to become uniform and homogeneous horizontally but not vertically, because the temperature and pressure decrease with altitude.

In order to understand the nature of any air mass, three factors should be especially taken into account. The most important of these factors is the *source region* of the air mass. The source region is defined as the region on the surface of the Earth where the air mass originally acquired its fundamental properties. The second factor is the *path* followed by the air mass after leaving

its source. The properties of the air mass are modified according to its path. If, for example, a warm air mass passes over a cool region, it will tend to become cooler. The third factor is the *age* of the air mass in terms of time which has elapsed since its departure from the source region. The original properties of an air mass are modified by its age.

Meteorologists divide air masses into two broad groups, depending on the latitudinal extent of the source regions. The first group is that of polar air masses while the second is that of tropical air masses. Each of these groups has been further sub-divided into continental or maritime. Thus, there are four main types of air masses as shown in Table 7.

TABLE 8
The Classification of Air Masses

Major Group	*Sub-group*	*Source Regions*	*Properties at Source*
Polar (P)	Maritime Polar (mP)	Oceans north or south of approx. 50° N. lat.	Cool, rather damp, unstable
	Continental Polar (cP)	Continents in vicinity of Arctic Circle; Antarctica	Cold and dry; very stable
Tropical (T)	Maritime Tropical (mT)	Trade Wind belt and sub-tropical waters of great oceans	Moist and warm; stability variable; stable on east side of great oceans, rather unstable on west
	Continental Tropical (cT)	Low latitude deserts, chiefly Sahara and Australian deserts	Hot and very dry; unstable

Each of the types mentioned above has its characteristic weather conditions.

The continental polar (cP) air mass originates over the northern parts of America and Eurasia. During winters the tempera-

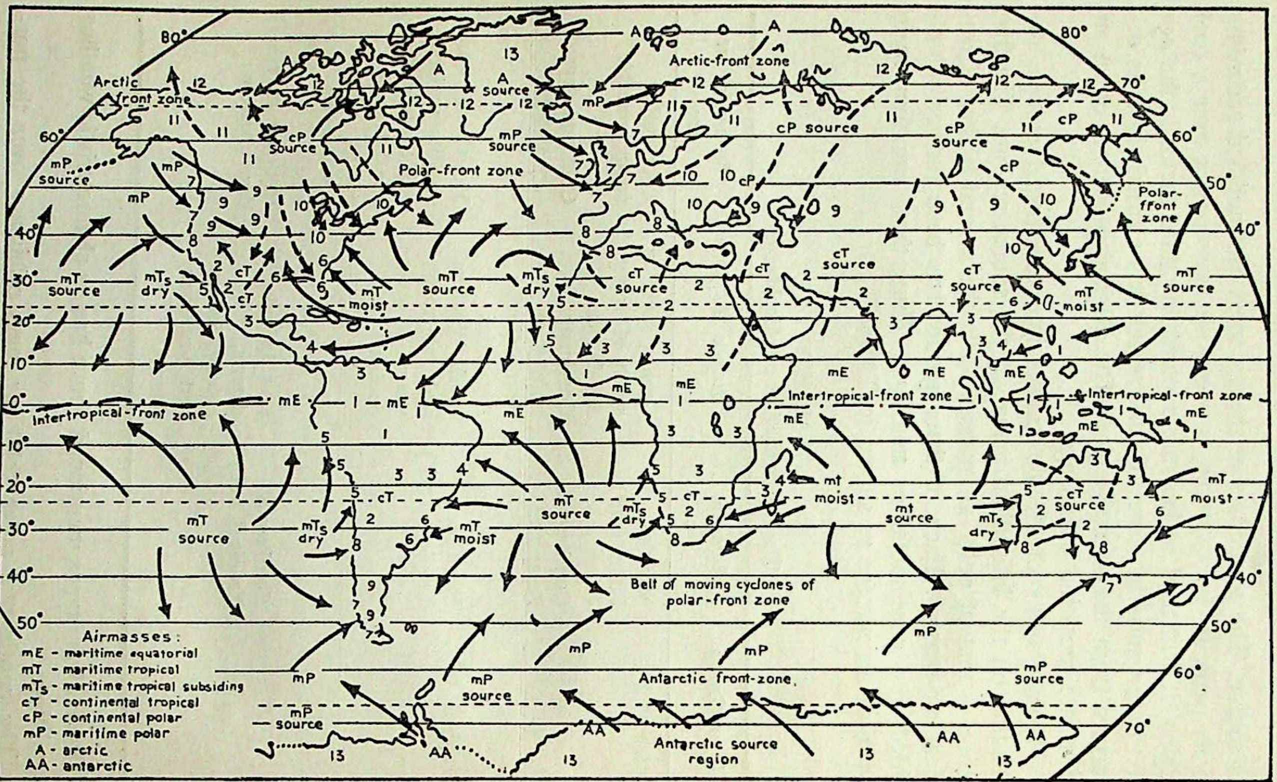


Fig. 24—AIR MASSES

ture in these regions is extremely low because of prolonged radiative cooling as well as the absence of the moderating influence of the oceans. Consequently, anticyclones tend to form in these regions very frequently. The continental polar air mass is generated within these high pressure systems. Adjacent to the Earth's surface, there is a shallow layer of very cold and dry air, but beyond the altitude of 10,000 ft. the air remains comparatively warm. This arrangement of cool and warm layers is responsible for the marked stability of the cP air mass. Under the influence of the cold dry layer of air adjacent to the Earth, the weather over the continents is clear, cold and sparkling.

Conditions are different during summers. The anticyclones are less frequent. There is, therefore, an influx of air in the polar and sub-polar regions from other sources. The nature of the cP air mass also undergoes a change. It becomes fairly warm near the Earth's surface, but often remains cool in the higher altitudes. It is, therefore, much less stable in summer than in winter.

The maritime polar (mP) air mass acquires its fundamental properties over the northern parts of the great oceans in the northern hemisphere or over the stormy belt beyond 50° S. latitude. The mP air is generally cP air which has journeyed over water bodies for a fairly long time. The cool and dry lower layer of the cP air comes in contact with the comparatively warm and damp surface of the oceans. It is rapidly warmed and moistened at the surface. The air mass, consequently, becomes unstable. The degree of instability depends upon the length of time the air has been lying over the ocean.

The continental tropical (cT) air mass is a rare phenomenon. It is formed chiefly over deserts in the Torrid Zone, the main source regions being the Sahara, the Australian desert and the south-western U.S.A. and Mexico. Because of the high temperatures prevalent at the source, the cT air mass is very hot. The weather is cloudless because of the extreme dryness of the air. The air mass is unstable.

The maritime tropical (mT) air mass has its source in the Trade Wind belt and the tropical anticyclones over the oceans. It is an air mass of fairly high temperature and humidity and is generally associated with clear skies and stability. It travels pole-

wards in broad invasions and exerts considerable influence on the weather of the sub-tropical regions.

Air masses possessing different properties may come in contact with each other. Two unlike air masses are generally separated by a sloping boundary surface, which is known as the *frontal surface*. The line along which this surface intersects with the ground surface is called a *front*.

The process of formation of fronts or the strengthening of weak and decaying fronts is called *frontogenesis*. The opposite process, i.e., the process of the weakening or destruction of fronts, is termed *frontolysis*.

Fronts may either be warm or cold. At a warm front, warm air advances against cold air and is forced upwards over an underlying wedge of cold air. This phenomenon influences the weather conditions considerably. The ascent of the warm air leads to the formation of clouds and precipitation, the amount of cloudiness and precipitation depending on the existing humidity and the rate of cooling of the warm air.

At a cold front, cold air advances against warm air, replacing it and forcing it upwards. A cold front is steeper than a warm front. It slopes backward instead of forward. Cloudiness and rainfall depend on the vertical structure of the warm air. Usually, a cold front has a narrow band of clouds, but the amount of precipitation is considerable.

Sometimes warm and cold fronts merge to form an *occluded* front. In such circumstances, the warm sector is shut off from the surface. Formation of clouds and precipitation takes place along the line of the occluded front.

Climate

Climate is the sum total of the general weather conditions of a particular region. The climate of any region has a profound influence on the life and culture of the people who live in it. It was no accident that the earliest civilizations developed in the sub-tropical climates in the valleys of the Nile, the Tigris-Euphrates and the Indus. The great deserts of the world, hot as well as cold, have always remained more or less empty. Although

people get used to a climate in which they live, it is generally thought that a cool temperate climate is the best for human comfort.[1]

The general climate zones of the world are: Equatorial, Sub-tropical, Temperate, and Polar. But the climate of any region is modified by several factors such as elevation above the sea level and the position of the region with reference to oceans, continents and mountains.

We cannot escape the climate and the weather. It is true that we can eliminate the weather variation and produce ideal working condition inside a particular building by air-conditioning. But we shall always have to reckon with the weather.

[1] Note the influences of climatic conditions of Europe on European painting in *An Introduction to European Painting* and of Indiain climatic conditions on Indian Art and Music in *An outline of Indian painting* and *An Introduction to Hindustani Music*—all these publications have been published under the General Education Reading Material Project. A discussion on this topic may also be found in *Indian Culture*, another Project publication.

CHAPTER SEVEN

YOURS IS THE EARTH

IN the beginning of this book we said that notwithstanding the insignificance of the Earth in the entire scheme of the Universe, our planet is a wonderful home. In the subsequent chapters we studied some important facts about the physical environment of this planet, i.e., about the three great realms of land (lithosphere), water (hydrosphere) and air (atmosphere).

There are various kinds of physical environments on the surface of the Earth, and the life and work of the people of any region as well as the density of population in that region depends upon the nature of the local physical environment. The factors which constitute the physical environment are location, relief, climate, natural vegetation, soil and minerals. These factors influence the ways in which people fulfil their basic needs (food, clothing and shelter), as well as their higher needs (education, entertainment, culture, government, etc.). Primitive people are much more under the control of their environment than advanced people for they are more or less content with what their environment offers them. Advanced people, however, try to modify their environment in order to overcome its difficulties or to make it more productive. Some of the examples of the modification of environment by the advanced people are the reclamation of marshes, the irrigation of dry lands, the cutting down of forests, the establishment of agriculture, the working of mines and the building of towns and means of communication.

Let us examine some of the geographical factors constituting any physical environment. The location of a region is an important factor, for it influences the climate as well as the degree of accessibility of that region. The location of the Tundra makes its climate excessively cold; the location of Tibet makes it almost inaccessible.

The relief of a region greatly influences the life of the people. It has already been mentioned in the previous pages that in the rugged mountains, life is usually much more difficult and the population generally much smaller than on the plains.

The climate of a region affects the life of its people in many ways. Extremely hot or cold regions as well as excessively dry or humid areas are usually sparsely populated. The possibility of agriculture and the nature of crops is markedly governed by the climate of a place.

The natural vegetation of a region has a significant influence on man's life, since it may provide material for clothing and houses and timber for a lumbering industry. Natural grasslands may provide the basis for cattle grazing, while forests which are dense and difficult to clear are usually sparsely populated.

The nature of the soil determines the possibility of agriculture and the type of crops which may be grown in a region.

The occurrence and exploitation of minerals is an important factor, for it influences the location of mining industries and consequently the distribution and density of population. Even in inhospitable regions pockets of population are found in places where minerals occur.

The geographical factors mentioned above have a great bearing on the occupations followed by the people. Broadly speaking, these occupations include (*a*) gathering or collecting food from plants and animals, (*b*) fishing, hunting and trapping, (*c*) lumbering, (*d*) mining, (*e*) farming, (*f*) manufacturing, (*g*) trade and transport, and (*h*) the professions. The first four groups of occupations depend upon what the physical environment provides in the form of natural vegetation, wild animals and mineral deposits. They are called "robber occupations" because they rob the land and do not give anything to it in return of what they take from it. In the fifth group, i.e., farming, man makes use of the natural resources of soil, water and sunshine and controls the reproduction of plants and animals. The remaining occupations, manufacturing, trade and transport and professions are less directly dependent on the physical environment.

It is through these occupations that man provides for his basic needs as well as for his higher needs. In primitive societies these needs are relatively simple, so that the number of occupations are limited, while in advanced societies the needs are complex, so that the occupational opportunities are also great.

Most of the people in the world lead a settled life, but there still exist some nomadic people who depend on plants and ani-

mals for their food, their main occupations being food-gathering, fishing, hunting and grazing. It is obvious that generally the settled people are more advanced than the nomadic people.

As man grows wiser and begins to apply his knowledge to exploit and improve his physical environment, in other words, as he becomes more civilized, he is able to build up a better and richer life for himself. He irrigates land, clears forests, practises agriculture, mining and stock-raising, builds towns, ports and means of communication and conquers diseases. In changing his environment he changes himself.

It is true that there are large areas in the world where man has had little success and which remain inhospitable. There are, for example, the frozen wastes of the Tundra, or expanses of the hot deserts like the Sahara, or the great stretches of equatorial forests like the Congo, which are difficult to inhabit. But man has been gradually learning to utilize the resources of even these difficult regions.

Ours is the Earth, and it is for us to make use of the resources which it has to offer. We can even create new resources with the help of science and technology. It is for us to decide whether we want to be the slaves or the masters of our physical environment. Surely, one cannot control environment in every respect, but the hallmark of progress is to control it as much as possible.

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THE EARTH WE LIVE ON

The Earth We Live On covers the fundamentals of physical geography which may be regarded as a body of basic principles of earth sciences. The material in the book is presented in such a way as to stimulate the interest of the reader and to provide him with a usable, simplified body of knowledge which is an important part of the foundation for studies of human geography.

The realization that students offering geography as a subject at the university level generally lack a proper understanding of the fundamentals of the science, prompted the writing of this book. It was also felt that all intelligent people should have some knowledge of the earth on which they live — its nature and place in the universe, its physical laws and phenomena, its resources and people.

Among the topics dealt with in the book are: the condensation and stratification of the earth; the formation of mountains and seas; trade winds; seasons; the evolution of plant and animal life; stars and galaxies; the rotation and revolution of the earth. References to not too well-known geographical facts, such as the international date line, the earth as the clock of life, and Laplace's hypothesis of planetary formation will be found interesting and instructive. The book, which is copiously illustrated, is intended not only for the benefit of students, but for teachers of geography as well.

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